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# Information Technology Division's Technical Paper Abstracts

CATHY J. WILEY

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Vienna, VA

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13. ABSTRACT (Maximum 200 words)  "Information Technology Division's Technical Paper Abstracts 1993" documents the accomplishments of projects at the seven branches of the Information Technology Division. The seven branches are: Navy Center for Applied Research in Artificial Intelligence (NCARAI) including: machine learning, intelligent decision aids, interactive systems, sensor-based systems, and neural networks; Communications Systems; Human-Computer Interaction; Center for Computer High Assurance Systems; Transmission Technology; Advanced Information Technology; and Center for Computational Sciences. Points of contact are indicated for acquiring additional technical information about the projects, and an order form is provided for obtaining copies of the publications abstracted.				
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## I. INTRODUCTION

The Information Technology Division (ITD) is one of the largest Divisions at NRL. The technical areas of expertise in ITD include:

## Artificial Intelligence

- intelligent simulation
- adaptive control software
- machine learning methods
- robotic vision and control
- interactive systems
- intelligent decision aids
- reasoning under uncertainty

## Software

computer security (COMPUSEC)  
network security  
software assurance  
software specification methodology  
hard real time (HRT) computing  
adaptive software testing methods  
information security (INFOSEC)

## Communications

network simulation  
HF communications  
communication security (COMSEC)  
communications networking

## Human-Computer Interaction

- metrics and evaluation
- speech communication systems
- human-computer dialog
- visualization techniques

## Decision Support Systems

- prototyping techniques
- distributed decision support
- distributed simulation
- parallel processing techniques

ITD has more than 220 civilian employees organized into seven branches: the Navy Center for Applied Research in Artificial Intelligence, Communication Systems, Human-Computer Interaction Laboratory, Center for Computer High Assurance Systems, Transmission Technology, Advanced Information Technology, and Center for Computational Sciences.

[illegible]

## **II. NAVY CENTER FOR APPLIED RESEARCH IN ARTIFICIAL INTELLIGENCE CODE 5510**

The Navy Center for Applied Research in Artificial Intelligence (NCARAI) is part of the Information Technology Division within the Naval Research Laboratory (NRL). NCARAI is engaged in research and development efforts designed to address the application of artificial intelligence (AI) technology and techniques to critical Navy and national problems. The emphasis at NCARAI is the linkage of theory and application in demonstration projects that use a full spectrum of AI methods.

The technical papers and reports of NCARAI document the accomplishments of projects in machine learning, natural language understanding, intelligent decision aids, and intelligent systems for robotic sensing and control. Innovative basic and exploratory research in these areas is made possible by NCARAI's staff of 35 individuals comprising an extraordinary cross section of AI talent from the government civilian and military sectors, visiting scientists from universities, and consulting scientists from industry. An ongoing seminar series, featuring notable scientists from academic and industrial research communities, as well as the military services, provides an excellent opportunity to exchange information and maintain awareness of current developments.

Persons interested in acquiring additional information about the reported results are encouraged to contact the relevant technical personnel for whom e-mail addresses have been provided.

---

## MACHINE LEARNING

**Title:** User's Guide for SAMUEL, Version 3  
**Author(s):** John J. Grefenstette and Helen G. Cobb  
**E-mail Address:** gref@aic.nrl.navy.mil or cobb@aic.nrl.navy.mil  
**Citation:** Internal report  
**Date:** 1993  
**Report No.:** AIC-93-001

### Abstract

SAMUEL was designed as a platform to investigate the application of machine learning techniques for the design of intelligent systems. The basic approach is to enable a system to explore a range of behavior within a simulation model, using feedback to revise its decision strategies over time. The ultimate goal is to design a system that, with a minimum of externally provided guidance, can refine and improve upon its initial knowledge. This goal has led to our adoption of rule representations that should ease the expression of manually derived strategies.

A second theme in this project is that adaptation can be driven by competition among knowledge structures. Competition is applied at two levels in SAMUEL. Within a strategy composed of decision rules, rules compete with one another to influence the behavior of the system. At a higher level of granularity, entire strategies compete with one another using a genetic algorithm. Genetic algorithms provide a robust approach to searching extremely large and complex spaces, such as the space of strategies.

---

**Title:** Assimilating Advice in Embedded Agents  
**Author(s):** Diana F. Gordon and Devika Subramanian  
**E-mail Address:** gordon@aic.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** AIC-93-002

### Abstract

In this paper, we address the problem of designing and refining strategies for agents embedded in dynamic, multi-agent worlds. We use high-level advice given by an expert, as well as knowledge of the domain dynamics, to design a parametric action map from an agent's sensors and its internal state to its effectors. A genetic algorithm (GA) refines the action map as the agent dynamically interacts with the environment. We compare the performance of our multistrategy learner with advice against the GA without advice. Our multistrategy learner converges substantially faster and, in many cases, to a more accurate solution, than a GA without advice in two complex simulated domains, and performs well on navigation with a Nomad 200 robot. Here, we experimentally identify and analyze the conditions under which high-level advice can be expected to significantly improve the design of task-level strategies.

---

**Title:** Finding a Small Set of N-Dimensional, Integer-Valued Points using a Specialized Genetic Algorithm  
**Author(s):** Helen G. Cobb  
**E-mail Address:** cobb@aic.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** July 1993  
**Report No.:** AIC-93-003

**Abstract**

This paper describes a specialized genetic algorithm, called GAvect (GA for vector search), that finds a small set of points in a larger space of N-dimensional, integer-valued points. These points can act as representative points of a larger space. For example, the points can be centroids or upper boundary limits that partition the space of another learning subsystem. GAvect is similar in basic structure to the standard generational genetic algorithm (GA), but the representation of the population members and the genetic operators are specialized to enable a search for a set of points. Each member of GAvect is a variable length vector of points, ranging from one point to some maximum number specified on input. GAvect finds a set of points that reflect the environment's evaluation function. Current test results show that GAvect works well in finding a small number of points in a large space where the environment's evaluation is the distance of a trial vector from the environment's vector based on a nearest neighbor mapping. The approach is also applied to the problem of finding a set of points that specify the best partition of a reinforcement learner's search space. Future studies will examine ways of enhancing the overall performance of the system. In addition, the effectiveness of the system will be explored using other learning subsystems and learning tasks.

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**Title:** Genetic Algorithms for Tracking Changing Environments  
**Author(s):** Helen G. Cobb and John J. Grefenstette  
**E-mail Address:** cobb@aic.nrl.navy.mil or gref@aic.nrl.navy.mil  
**Citation:** Fifth International Conference on Genetic Algorithms (ICGA 93), 523-530, Morgan Kaufmann  
**Date:** July 17-21, 1993  
**Report No.:** AIC-93-004

**Abstract**

In this paper, we continue to explore the use of alternative mutation strategies as a means of increasing diversity in the Standard GA so that the GA can track the optimum of a changing environment. This paper presents the first systematic study that contrasts three difference strategies: the Standard GA using a constant, high level of mutation, a mechanism called Random Immigrants, that replaces part of the population each generation with randomly generated values, and an adaptive mechanism called Triggered Hypermutation, that increases the mutation rate whenever there is a degradation in the performance of the time-averaged best performance. The study examines each of these strategies in the context of several kinds of environmental change, including: linear translation, random movement of the location of the maximum mound, oscillation with a small amount of change between two landscapes, and oscillation between two significantly difference landscapes. In addition, the study examines the performance of the mechanisms in a stationary environment. The results show that the different mechanisms tend to work better in different kinds of environments. Future research will examine the possibility of combining aspects of these strategies so that a modified GA can work well in both stationary and nonstationary environments.

---

**Title:** Case-Based Initialization of Genetic Algorithms  
**Author(s):** Connie Loggia Ramsey and John J. Grefenstette  
**E-mail Address:** ramsey@aic.nrl.navy.mil or gref@aic.nrl.navy.mil  
**Citation:** Fifth International Conference on Genetic Algorithms (ICGA 93), 84-91, Morgan Kaufmann  
**Date:** July 17-21, 1993  
**Report No.:** AIC-93-005

**Abstract**

In this paper, we introduce a case-based method of initializing genetic algorithms that are used to guide search in changing environments. This is incorporated in an anytime learning system. Anytime learning is a general approach to continuous learning in a changing environment. The agent's learning module continuously tests new strategies against a simulation model of the task environment, and dynamically updates the knowledge base used by the agent on the basis of the results. The execution module includes a monitor that can dynamically modify the simulation model based on its observations of the external environment; an update to the simulation model causes the learning system to restart learning. Previous work has shown that genetic algorithms provide an appropriate search mechanism for anytime learning. This paper extends the approach by including strategies, which are learned under similar environmental conditions, in the initial population of the genetic algorithm. Experiments show that case-based initialization of the population results in a significantly improved performance.

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**Title:** Combining Experience with Quantitative Models  
**Author(s):** John J. Grefenstette and Connie Loggia Ramsey  
**E-mail Address:** gref@aic.nrl.navy.mil or ramsey@aic.nrl.navy.mil  
**Citation:** AAAI-93 Workshop on Learning Action Models, Wei-Min Shen (Chairperson) with Microelectronics and Computer Technology Corporation in Austin, TX  
**Date:** March 11, 1993  
**Report No.:** AIC-93-007

**Abstract**

This is a progress report on our efforts to design intelligent robots for complex environments. The sort of applications we have in mind include sentry robots, autonomous delivery vehicles, undersea surveillance vehicles, and automated warehouse robots. We are investigating the issues relating to machine learning, using multiple mobile robots to perform tasks such as playing hide-and-seek, tag, or competing to find hidden objects. We propose that the knowledge acquisition task for autonomous robots be viewed as a cooperative effort between the robot designers and the robot itself. The robot should have access to the best model of its world that the designer can reasonably provide. On the other hand, some aspects of the environment will be unknown in advance. For such aspects, the robot itself is in the best position to acquire the knowledge of what to expect in its world. We have implemented these ideas in an arrangement we call "case-based anytime learning." This system starts with a parameterized model of its world and then learns a set of specific models that correspond to the environmental cases it actually encounters. The system uses genetic algorithms to learn high-performance reactive strategies for each environmental model.

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**Title:** Genetic Algorithms Are NOT Function Optimizers  
**Author(s):** Kenneth A. De Jong  
**E-mail Address:** dejong@aic.nrl.navy.mil  
**Citation:** Foundations of Genetic Algorithms Workshop•2, L. Darrell Whitley, editor, 5-17, Morgan Kaufmann  
**Date:** 1993  
**Report No.:** AIC-93-008

**Abstract**

Genetic Algorithms (GAs) have received a great deal of attention regarding their potential as optimization techniques for complex functions. The level of interest and success in this area has led to a number of improvements to GA-based function optimizers and a good deal of progress in characterizing the kinds of functions that are easy/hard for GAs to optimize. With all this activity, there has been a natural tendency to equate GAs with function optimization; however, the motivating context of Holland's initial GA work was the design and implementation of robust adaptive systems. In this paper we argue that a proper understanding of GAs in this broader adaptive systems context is a necessary prerequisite for understanding their potential application to any problem domain. We then use these insights to better understand the strengths and limitations of GAs as function optimizers.

---

**Title:** Generation Gaps Revisited  
**Author(s):** Kenneth A. De Jong and Jayshree Sarma  
**E-mail Address:** dejong@aic.nrl.navy.mil  
**Citation:** Foundations of Genetic Algorithms Workshop•2, L. Darrell Whitley, editor, 19-28, Morgan Kaufmann  
**Date:** 1993  
**Report No.:** AIC-93-009

**Abstract**

There has been a lot of recent interest in so-called "steady state" genetic algorithms (GAs) which, among other things, replace only a few individuals (typically 1 or 2) each generation from a fixed size population of size N. Understanding the advantages and/or disadvantages of replacing only a fraction of the population each generation (rather than the entire population) was a goal of some of the earliest GA research. In spite of considerable progress in our understanding of GAs since then, the pros/cons of overlapping generations remains a somewhat cloudy issue. However, recent theoretical and empirical results provide the background for a much clearer understanding of this issue. In this paper we review, combine, and extend these results in a way that significantly sharpens our insight.

---

**Title:** On the State of Evolutionary Computation  
**Author(s):** K.A. De Jong and W.M. Spears  
**E-mail Address:** dejong@aic.nrl.navy.mil or spears@aic.nrl.navy.mil  
**Citation:** Fifth International Conference on Genetic Algorithms (ICGA 93), 618-623, Morgan Kaufmann  
**Date:** July 17-21, 1993  
**Report No.:** AIC-93-010

**Abstract**

In the past few years the evolutionary computation landscape has been rapidly changing as a result of increased levels of interaction between various research groups and the injection of new ideas which challenge old tenets. The effect has been simultaneously exciting, invigorating, annoying, and bewildering to the old-timers as well

as the new-comers to the field. Emerging out of all of this activity are the beginnings of some structure, some common themes, and some agreement on important open issues. We attempt to summarize these emergent properties in this paper.

---

**Title:** An Overview of Evolutionary Computation

**Author(s):** William M. Spears, Kenneth A. De Jong, et al

**E-mail Address:** spears@aic.nrl.navy.mil or dejong@aic.nrl.navy.mil

**Citation:** Proceedings of the European Conference on Machine Learning (ECML93), 442-459, v667, Springer-Verlag

**Date:** April 1993

**Report No.:** AIC-93-011

#### **Abstract**

Evolutionary computation uses computational models of evolutionary processes as key elements in the design and implementation of computer-based problem solving systems. In this paper we provide an overview of evolutionary computation, and describe several evolutionary algorithms that are currently of interest. Important similarities and differences are noted, which lead to a discussion of important issues that need to be resolved, and items for future research.

---

**Title:** Genetic Algorithms and Machine Learning

**Author(s):** John J. Grefenstette

**E-mail Address:** gref@aic.nrl.navy.mil

**Citation:** Paper Presented at the Sixth Annual ACM Conference on Computational Learning Theory (COLT 93), 3-4, ACM Press

**Date:** July 26-28, 1993

**Report No.:** AIC-93-012

#### **Abstract**

One approach to the design of learning systems is to extract heuristics from existing adaptive systems. Genetic algorithms are heuristic learning models based on principles drawn from natural evolution and selective breeding. Some features that distinguish genetic algorithms from other search methods are:

- 1) A population of structures that can be interpreted as candidate solutions to the given problem;
- 2) The competitive selection of structures for reproduction, based on each structure's fitness as a solution to the given problem;
- 3) Idealized genetic operators that alter the selected structures in order to create new structures for further testing.

In many applications, these features enable the genetic algorithm to rapidly improve the average fitness of the population and to quickly identify the high performance regions of very complex search spaces. In practice, genetic algorithms may be combined with local search techniques to create a high-performance hybrid search algorithm. This article provides a survey of recent advances in the application of genetic algorithms to problems in machine learning.

---

**Title:** Machine Learning Systems: Part II - Concept Learning from Examples with ID3 and Related Systems

**Author(s):** Diana F. Gordon, William M. Spears, and Kenneth A. De Jong

**E-mail Address:** gordon@aic.nrl.navy.mil, spears@aic.nrl.navy.mil, or dejong@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-013

**Abstract**

This is the second in a series of reports designed to acquaint Navy and other military personnel with current software available for machine learning. By acquainting personnel with the available software, we are encouraging the applicability of learning systems to problems of military interest. This report focuses on ID3 and related systems. ID3 is a concept learning system that is designed to handle large quantities of data that may be noisy.

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**Title:** A NN Algorithm for Hard Satisfiability Problems

**Author(s):** William M. Spears

**E-mail Address:** spears@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-014

**Abstract**

Satisfiability (SAT) refers to the task of finding a truth assignment that makes an arbitrary boolean expression true. This paper compares a neural network algorithm (NNSAT) with GSAT (Selman *et al.*, 1992), a new greedy algorithm for solving satisfiability problems. GSAT can solve hard problem instances that are extremely difficult for traditional satisfiability algorithms. Results indicate that although NNSAT spends more time "thinking" about which assignment to try next, it searches far fewer assignments before a satisfying assignment is found.

---

**Title:** Simulated Annealing for Hard Satisfiability Problems

**Author(s):** William M. Spears

**E-mail Address:** spears@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-015

**Abstract**

Satisfiability (SAT) refers to the task of finding a truth assignment that makes an arbitrary boolean expression true. This paper compares a simulated annealing algorithm (SASAT) with GSAT (Selman *et al.*, 1992), a greedy algorithm for solving satisfiability problems. GSAT can solve problem instances that are extremely difficult for traditional satisfiability algorithms. Results indicate that SASAT solves at least as many hard SAT problems with far less effort. Furthermore, SASAT scales up better as the number of variables increases.

---

**Title:** A Multistrategy Learning Scheme for Assimilating Advice in Embedded Agents  
**Author(s):** Diana F. Gordon and Devika Subramanian  
**E-mail Address:** gordon@aic.nrl.navy.mil  
**Citation:** Proceedings of the Second International Workshop on Multistrategy Learning, 218-233, George Mason University, AI Center  
**Date:** May 1993  
**Report No.:** AIC-93-016

**Abstract**

The problem of designing and refining task-level strategies in an embedded multiagent setting is an important unsolved question. To address this problem, we have developed a multistrategy system that combines two learning methods: operationalization of high-level advice provided by a human and incremental refinement by a genetic algorithm. The first method generates seed rules for finer-grained refinements by the genetic algorithm. Our multistrategy learning system is evaluated on two complex simulated domains as well as with a Nomad 200 robot.

---

**Title:** Learning Singly-Recursive Relations from Small Datasets  
**Author(s):** David W. Aha, Charles X. Ling, Stan Matwin, and Stephane Lapointe  
**E-mail Address:** aha@aic.nrl.navy.mil  
**Citation:** Workshop on Inductive Logic Programming at the 1993 International Joint Conference on Artificial Intelligence  
**Date:** July 1993  
**Report No.:** AIC-93-017

**Abstract**

The inductive logic programming system LOPSTER was created to demonstrate the advantage of basing induction on logical implication rather than 0-subsumption. LOPSTER's sub-unification procedures allow it to induce recursive relations using a minimum number of examples, whereas inductive logic programming algorithms based on 0-subsumption require many more examples to solve induction tasks. However, LOPSTER's input examples must be carefully chosen; they must be along the same inverse resolution path. We hypothesize that an extension of LOPSTER can efficiently induce recursive relations without this requirement. We introduce a generalization of LOPSTER named CRUSTACEAN that has this capability and empirically evaluate its ability to induce recursive relations.

---

**Title:** Using Queries to Adjust the Bias During Concept Learning  
**Author(s):** Diana F. Gordon  
**E-mail Address:** gordon@aic.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** AIC-93-018

**Abstract**

This paper describes an approach to bias adjustment for incremental concept learning that involves testing assumptions about the bias. These assumptions state the irrelevance of portions of the hypothesis language bias. Queries to an oracle test the validity of these assumptions. Following each assumption test, the bias is adjusted as needed based on the test results.

The oracle that responds to our system's queries is expected to be human in most cases. We wish to place the bulk of the knowledge acquisition burden on the system,

rather than the human expert. Therefore, rather than expecting the expert to convert his/her expertise into rules, our system only requires "yes/no" answers to simple queries.

In this paper, we present our approach, followed by theoretical and empirical evaluations. From these evaluations we are able to characterize the situations in which our bias testing and adjustment method is most appropriate. When it is most appropriate, our method can produce an order of magnitude improvement in the rate of convergence to the concept over a baseline performance.

---

**Title:** Simple Subpopulation Schemes  
**Author(s):** William M. Spears  
**E-mail Address:** spears@aic.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** AIC-93-020

**Abstract**

This paper considers a new method for maintaining diversity by creating subpopulations in a standard generational evolutionary algorithm. Unlike other methods, it replaces the concept of distance between individuals with tag bits that identify the subpopulation to which an individual belongs. Two variations of this method are presented, illustrating the feasibility of this approach. The implications this has on multimodal function optimization are also discussed.

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**Title:** Learning Action Models as Reactive Behaviors  
**Author(s):** Alan C. Schultz and John J. Grefenstette  
**E-mail Address:** schultz@aic.nrl.navy.mil or gref@aic.nrl.navy.mil  
**Citation:** Proceeding of the Workshop on Learning Action Models, AAAI-93, Washington DC  
**Date:** July 11, 1993  
**Report No.:** AIC-93-022

**Abstract**

Autonomous vehicles will require both projective planning and reactive components in order to perform robustly. Projective components are needed for long-term planning and replanning where explicit reasoning about future states is required. Reactive components allow the system to always have some action available in real-time, and themselves can exhibit robust behavior, but lack the ability to explicitly reason about future states over a long time period. This work addresses the problem of learning reactive components (normative action models) for autonomous vehicles from simulation models. Two main thrusts of our current work are described here. First, we wish to show that behaviors learned from simulation are useful in the actual physical system operating in the real world. Second, in order to scale the technique, we demonstrate how behaviors can be built up by first learning lower level behaviors, and then fixing these to use as base components of higher-level behaviors.

---

**Title:** A Pruning Algorithm for Imperfect Information Games  
**Author(s):** Michael van Lent and David Mutchler  
**E-mail Address:** library@aic.nrl.navy.mil  
**Citation:** AAAI Fall Symposium Series, Games: Planning and Learning  
**Date:** October 1993  
**Report No.:** AIC-93-025

**Abstract**

IMP-minimax is the analog to minimize for games with imperfect information, like card games such as bridge or poker. It computes an optimal strategy for the game if the game has a single player and a certain natural property called perfect recall. We introduce an algorithm, IMP-alpha-beta that is to IMP-minimax as alpha-beta is to minimax. That is, IMP-alpha-beta computes the same value as IMP-minimax does, but usually faster through pruning (i.e., not examining the value of some leaves). IMP-alpha-beta includes common pruning techniques and introduces a new technique, information set pruning. We suggest a natural model in which to study the performance of search algorithms for imperfect information games and analyze IMP-alpha-beta in the context of that model. Our analysis includes both theorems bounding the performance of IMP-alpha-beta and empirical data indicating its average-case behavior.

---

**Title:** Inverting Implication with Small Training Sets  
**Author(s):** David W. Aha, Stephane Lapointe, Charles X. Ling, and Stan Matwin  
**E-mail Address:** aha@aic.nrl.navy.mil  
**Citation:** 1994 European Conference on Machine Learning (ECML-94), Francesco Bergadano and Lu De Raedt (editors), 31-48, v784, Springer-Verlag  
**Date:** April 1994  
**Report No.:** AIC-93-031

**Abstract**

This paper addresses an important inductive logic programming (ILP) task: induction of recursive clauses using inverse implication (rather than inverse resolution) as the underlying generalization method. The approach presented here applies to a class of logic programs similar to the class of primitive recursive functions. Induction is performed using a small number of examples (typically, just two) of the clause to be induced. No knowledge of the recursive definition's base clause is required of the user, and there is no prescribed relationship between the examples submitted to the system. The algorithm presented in this paper, implemented in a system named CRUSTACEAN, is based on locating matched lists of generating terms that determine the pattern of decomposition exhibited in the (target) recursive clause. Theoretical analysis gives the definition of the class of logic programs for which our approach is complete. An interesting feature of this class is that it is described in terms characteristic of other ILP approaches, such as 0-subsumption and the  $n^{th}$  root of a recursive clause. Empirical evaluation indicates considerable speedup in comparison with results previously reported using an earlier implementation of CRUSTACEAN. Finally, we describe how our approach is related to other recent work on inducing recursive clauses.

---

**Title:** Learning to Catch: Applying Nearest Neighbor Algorithms to Dynamic Control Tasks

**Author(s):** David W. Aha and Steven L. Salzberg

**E-mail Address:** aha@aic.nrl.navy.mil or salzberg@cs.jhu.edu

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-032

**Abstract**

This paper examines the hypothesis that local weighted variants of  $k$ -nearest neighbor algorithms can support dynamic control tasks. We evaluated several  $k$ -nearest neighbor ( $k$ -NN) algorithms on the simulated learning task of catching a flying ball. Previously, local regression algorithms have been advocated for this class of problems. These algorithms, which are variants of  $k$ -NN, base their predictions on a (possibly weighted) regression computed from the  $k$  nearest neighbors. While they outperform simpler  $k$ -NN algorithms on many tasks, they have trouble on this ball-catching task. We hypothesize that the non-linearities in this task are the cause of this behavior, and that local regression algorithms may need to be modified to work well under similar conditions.

---

**Title:** Test and Evaluation by Genetic Algorithms

**Author(s):** Alan C. Schultz, John J. Grefenstette, and Kenneth A. De Jong

**E-mail Address:** schultz@aic.nrl.navy.mil, gref@aic.nrl.navy.mil or dejong@aic.nrl.navy.mil

**Citation:** IEEE Expert, v8, n5, 9-14

**Date:** October 1993

**Report No.:** AIC-93-034

**Abstract**

Autonomous vehicles are likely to require sophisticated software controllers to maintain vehicle performance in the presence of vehicle faults. The test and evaluation of complex software controllers is expected to be a challenging task. The goal of this effort is to apply machine learning techniques from the field of artificial intelligence to the general problem of evaluating an intelligent controller for an autonomous vehicle. The approach involves subjecting a controller to an adaptively chosen set of fault scenarios within a vehicle simulator, and searching for combinations of faults that produce noteworthy performance by the vehicle controller. The search employs a genetic algorithm. We illustrate the approach by evaluating the performance of a subsumption-based controller for an autonomous vehicle. The preliminary evidence suggests that this approach is an effective alternative to manual testing of sophisticated software controllers.

---

## INTELLIGENT DECISION AIDS

**Title:** Study of Interval Belief Combination  
**Author(s):** Rangasami L. Kashyap and Liwu Chang  
**E-mail Address:** liwu@aic.nrl.navy.mil  
**Citation:** Journal of Intelligent and Robotic Systems, 7, 1-13  
**Date:** 1993  
**Report No.:** AIC-93-006

### Abstract

In this paper, we discuss the problem of combining interval beliefs that reflect the ignorance about the truth of a hypothesis. We propose a new mathematical procedure for combining different pieces of evidence which are represented in the interval form. The proposed approach utilizes a geometric model to carry out combination. Based on this approach, we could obtain combining operations which provide acceptable results in the conflicting cases as well as dependent evidences. Those combining rules possess several properties which often are not taken into account by other approaches in evidence combination. We compare results obtained from interval Bayes, Dempster-Shafer's combination rule and proposed rules and show that the values generated by proposed combining rules are in tune with our intuition.

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**Title:** A Case Study of Scaling Problems in Ship Classification  
**Author(s):** Scott Musman and Liwu Chang  
**E-mail Address:** liwu@aic.nrl.navy.mil  
**Citation:** Naval Research Laboratory Memorandum Report, NRL/MR/5513--93-7378  
**Date:** September 3, 1993  
**Report No.:** AIC-93-023

### Abstract

In the domain of ship classification there are potentially hundreds of candidate targets that can be observed. In the previous studies, we demonstrated the feasibility and applicability of using Bayesian belief networks to solve the ship classification problem with small examples. In this paper, we propose an approach for evaluating a large-scaled Navy ship classes model by virtue of a set of simple networks, each describing a single ship class. The final target ranking is based on the comparison of the measure of  $bel^*$  obtained from each ship class network. We claim that the functionality of the original ship classes model is preserved. Experimental results indicate that by combining the various techniques described separately in this and the previous papers, it is possible to create a target classification system which has the characteristics required for the ship classification problem.

---

**Title:** Application of a Real-Time Control Strategy for Bayesian Belief Networks to Ship Classification Problem Solving  
**Author(s):** Scott Musman, Liwu Chang and Lashon B. Booker  
**E-mail Address:** liwu@aic.nrl.navy.mil  
**Citation:** International Journal of Pattern Recognition and Artificial Intelligence, v7, n3, World Scientific Publishing  
**Date:** June 1993  
**Report No.:** AIC-93-024

### Abstract

In this paper, we present two levels of control scheme for solving ship classification problems in a timely manner. This scheme suggests specific ways in which



we can reduce the size of the belief networks in which we perform our belief computations, and also specifies measures which can be used to maximize the effectiveness of evidence acquisition. Measures are based on dynamic evidence prioritization techniques which reduce the number of queries we make to trigger the termination conditions. By combining them correctly we can reduce the amount of dynamic computation required during run-time, and thus improve the responsiveness of the system.

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**Title:** A Study of Scaling Issues in Bayesian Belief Networks for Ship Classification

**Author(s):** Liwu Chang and Scott Musman

**E-mail Address:** liwu@aic.nrl.navy.mil

**Citation:** 9th Conference on Uncertainty in Artificial Intelligence, Washington DC

**Date:** July 1993

**Report No.:** AIC-93-038

#### **Abstract**

The problems associated with scaling involve active and challenging research topics in the area of artificial intelligence. The purpose is to solve real world problems by means of AI technologies, in cases where the complexity of representation of the real world problem is potentially combinatorial. In this paper, we present a novel approach to cope with the scaling issues in Bayesian belief networks for ship classification. The proposed approach divides the conceptual model of a complex ship classification problem into a set of small modules that work together to solve the classification problem while preserving the functionality of the original model. The possible ways of explaining sensor returns (e.g., the evidence) for some features, such as portholes along the length of a ship, are sometimes combinatorial. Thus, using an exhaustive approach, which entails the enumeration of all possible explanations, is impractical for larger problems. We present a network structure (referred to as Sequential Decomposition, SD) in which each observation is associated with a set of legitimate outcomes which are consistent with the explanation of each observed piece of evidence. The results show that the SD approach allows one to represent feature-observation relations in a manageable way and achieve the same explanatory power as an exhaustive approach.

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**Title:** Transitioning Expert System Technology: Case Studies at the Navy Center for Applied Research in Artificial Intelligence

**Author(s):** Laura C. Davis, Alan L. Meyrowitz, and Randall P. Shumaker

**E-mail Address:** davis@aic.nrl.navy.mil

**Citation:** Proceedings of the Twenty-Sixth Annual Hawaii International Conference on System Sciences, VIII, 308-316, IEEE Computer Society Press

**Date:** January 5-8, 1993

**Report No.:** AIC-93-039

#### **Abstract**

Within the Department of Defense, a climate of budget cuts, personnel reductions, and renewed emphasis on research coordination and collaboration among the Services makes effective transition of developed technology from the research laboratory to the operational military more critical than ever before. This paper describes three case studies in expert or knowledge-based system technology development and transition at the Navy Center for Applied Research in Artificial Intelligence. Although quite different in methodological approach, the systems share a common development philosophy -- to construct prototypes as specialized reusable tools or shells rather than as simple technology demonstrations tailored to a particular application. The paper concludes with the identification and discussion of a number of critical issues in technology transition drawn from our experiences with and lessons learned from these efforts.

**Title:** Case-Based Sonogram Classification  
**Author(s):** David Aha and Patrick Harrison  
**E-mail Address:** aha@aic.nrl.navy.mil or harrison@aic.nrl.navy.mil  
**Citation:** NRL Formal Report, NRL/FR/5510--94-9707  
**Date:** January 31, 1994  
**Report No.:** AIC-93-041

**Abstract**

This report replicates and extends results reported by Naval Air Warfare Center (NAWC) personnel on the automatic classification of sonar images. They used novel case-based reasoning systems in their empirical studies, but did not obtain comparative analyses using standard classification algorithms. Therefore, the quality of the NAWC results were unknown. We replicated the NAWC studies and also tested several other classifiers (i.e., both case-based and otherwise) from the machine learning literature. These comparisons and their ramifications are detailed in this paper. Next, we investigated Fala and Walker's two suggestions for future work (i.e., on combining their similarity functions and on an alternative case representation). Finally, we describe several ways to incorporate additional domain-specific knowledge when applying case-based classifiers to similar tasks.

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**Title:** Memory Organization For Case-Based Reasoning  
**Author(s):** Patrick R. Harrison, Liwu Chang, and Alan Meyrowitz  
**E-mail Address:** harrison@aic.nrl.navy.mil, liwu@aic.nrl.navy.mil, or alanm@aic.nrl.navy.mil  
**Citation:** Second World Congress on Expert Systems, Lisbon Portugal  
**Date:** January 1994  
**Report No.:** AIC-93-042

**Abstract**

Heuristic adequacy and computational effectiveness are necessary attributes of reasoning systems. Heuristic adequacy means the representational system expresses fully the important attributes and semantics of the problem domain. Computational effectiveness requires that the resulting implementation work at the tempo expected of a human doing the same thing. Present systems provide heuristic adequacy at the expense of computational effectiveness and vice versa. This paper describes a model for case organization that might provide a useful guide for implementing heuristically adequate and computationally effective case-based reasoners. The guiding assumption states that a cognitively plausible model based in well-grounded theory is more likely to support these goals than one which ignores the underlying organization of memory.

---

**Title:** Panel on Behavior Certification  
**Author(s):** Patrick R. Harrison  
**E-mail Address:** harrison@aic.nrl.navy.mil  
**Citation:** Proceedings of the Design Principles and Engineering of Knowledge Based Systems Workshop, State University of New York at Utica-Rome Marcy, New York  
**Date:** June 8-9, 1993  
**Report No.:** AIC-93-043

**Abstract**

The goal of this panel was to identify basic and applied research and technology pertinent to the certification of intelligent systems (IS) and provide recommendations to the Joint Directors of Laboratories (JDL) on promising technologies and new directions.

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## INTERACTIVE SYSTEMS

**Title:** Focus of Attention In Decision Support Systems

**Author(s):** John Gurney, Elaine Marsh, and Ken Wauchope

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wauchope@aic.nrl.navy.mil

**Citation:** Proceedings of the 10th Annual Conference on Command and Control Decision Aids

**Date:** June 28-July 1, 1993

**Report No.:** AIC-93-019

### Abstract

In this paper, we argue that natural language interfaces with discourse capabilities have an important role to play in decision support systems, because such interfaces are responsive to focus of attention in the mind of a human decision maker. Decision support systems typically employ graphical user interfaces, which are characterized by strict ordering requirements for commands, no reference to previous operations, and an often arbitrary, redundant, and repetitive order of operations. Natural Language Interfaces (NLIs) allow English language commands and questions to be input either via a keyboard or using a speech input device in a relatively natural and easy way, and discourse capabilities allow a user to input commands or questions that are connected in some specifiable ways. We provide examples from three systems that have been developed at the Army Research Laboratory (ARL) and at the Naval Research Laboratory (NRL): the interface to the KOALAS Test Planning Tool (here called simply KOALAS for short), which simulates scenario-generated engagements between friendly and hostile fighter aircraft; the interface to the Combat Information Processor (CIP), which integrates, processes, and displays battlefield information for use by intelligence, and command and control officers; and the interface to TABS, an antisubmarine battle management system. We motivate and present a NL system that processes sequences of sentences that form cohesive discourses. The system represents and reasons about what the focus of attention is at a given time using Discourse Representation Theory (DRT). We consider focus of attention with respect to assertions, imperatives, and interrogative sentences, as well as issues of anaphora resolution and counterfactuals. We illustrate that interactions with such systems can be improved with the addition of natural language interfaces. NLIs can be added to systems after the initial development phase without loss of functionality. Furthermore we show that a hybrid natural language and graphical user interface with multi-modal capability improves access to decision aids more than either one independently and that natural language interfaces can help a user maintain his focus of attention in complex situations.

---

**Title:** Adding Speech Recognition to a Natural Language Interface

**Author(s):** Stephanie S. Everett, Kenneth Wauchope, and Dennis Perzanowski

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dennisp@aic.nrl.navy.mil

**Citation:** Journal of the American Voice I/O Society, v14, 41-52

**Date:** August 1993

**Report No.:** AIC-93-026

### Abstract

The addition of speech recognition capabilities would seem to be a logical and desirable extension to a keyboard-entry natural language understanding interface.

However, because of the limitations of some speech recognition technologies this addition can affect the structure and flexibility of the interface. This paper discusses the consequences and implications of this addition, and presents some of the lessons learned in adapting an existing natural language interface to accept spoken input.

---

**Title:** VIS/ACT: The Next Episode

**Author(s):** Tucker Maney and Henry Hamburger

**E-mail Address:** maney@aic.nrl.navy.mil or henryh@aic.nrl.navy.mil

**Citation:** 1993 Conference on Intelligent Computer-Aided Training and Virtual Environment Technology

**Date:** 5-7 May 1993

**Report No.:** AIC-93-029

**Abstract**

VIS/ACT is a multi-media educational system for aircrew coordination training (ACT). Students view video segments, answer questions that are adjusted to individual performance, and engage in related activities. Although the system puts the student in a reactive critiquing role, it has proved effective in improving performance on active targeted ACT skills, in group simulation tasks. VIS/ACT itself is the product of coordination among three Navy agencies.

---

## SENSOR-BASED SYSTEMS

**Title:** Propulsion and Guidance in a Simulation of the Worm, *C. Elegans*

**Author(s):** Ralph Hartley

**E-mail Address:** hartley@aic.nrl.navy.mil

**Citation:** From Animals to Animats 2: Proceedings of the 2nd International Conference on Simulation of Adaptive Behavior, edited by Jean-Arcady Meyer, Herbert L. Roitblat, and Stewart W. Wilson, 122-128, MIT Press

**Date:** 1993

**Report No.:** AIC-93-021

### Abstract

A simulation of the mechanics of the Nematode worm *C. Elegans* was constructed and used to study its locomotive behaviors. This simulation shed light on the mechanisms that must be used by any animal or robot using the same type of propulsion and also on aspects of the behavior of the real worm. The simulation of locomotion is an important step in the understanding of the overall behavior of an animal.

---

**Title:** Dynamical Neural Networks for Mobile Robot Control

**Author(s):** Brian Yamauchi

**E-mail Address:** yamauchi@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-033

### Abstract

This paper describes research in applying dynamical neural networks (DNNs) to the control of real mobile robots. Previous research had demonstrated the ability of DNNs to control autonomous agents in simulation, and this research was intended to investigate whether these results could be transferred to real world domains. These tasks were explored: predator avoidance, reactive navigation and landmark recognition. For the predator avoidance and landmark recognition tasks, a genetic algorithm was used to evolve DNN controllers in simulation. Then the networks were transferred to the mobile robot for evaluation. In the reactive navigation task, a hand-designed DNN controller was used in combination with algorithms for detecting static and cyclic behavior. In all three of these experiments, the control systems were able to successfully perform the tasks in both simulation and on the real robot.

---

**Title:** Vcalc: a 3-Space Vector Calculator

**Author(s):** Harold M. Greenwald and Frank J. Pipitone

**E-mail Address:** hal@aic.nrl.navy.mil or pipitone@aic.nrl.navy.mil

**Citation:** Naval Research Laboratory Memorandum Report, NRL/MR/5511--93-7422

**Date:** December 15, 1993

**Report No.:** AIC-93-035

### Abstract

Vcalc is a 3-space vector calculator providing graphic displays for vector and scalar operations. Designed to operate on a Sun Workstation, the program may be run stand-alone or as a debugging tool linked to a C program. It is a straightforward and useful tool whose development was motivated by the difficulty of debugging geometric programs.

---

**Title:** Extracting Elementary Surface Features Using Tripod Operators  
**Author(s):** Frank Pipitone  
**E-mail Address:** pipitone@aic.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** December 1993  
**Report No.:** AIC-93-036

**Abstract**

Tripod operators are a class of feature extraction operators for surfaces. They are useful for recognition and localization based on range or tactile data. They extract a few sparse point samples in a regimented way, so that  $N$  sampled surface points yield only  $N-3$  independent scalar features containing all the pose-invariant surface shape information in these points and no other information. They provide a powerful index into sets of prestored surface representations. A tripod operator consists of three points in 3-space fixed at the vertices of an equilateral triangle and a procedure for making several "depth" measurements in the coordinate frame of the triangle, which is placed on the surface like a surveyor's tripod. They have complete six DOF isometry invariance and can be used in many ways and on arbitrary surface shapes. Here we study the structure of tripod feature data on several commonly occurring simple surface types, with the goal of providing concise analytic expressions for mapping sparse surface samples into candidate surface types.

---

**Title:** Rapid Recognition of Freeform Objects in Noisy Range Images Using Tripod Operators  
**Author(s):** Frank Pipitone and William Adams  
**E-mail Address:** pipitone@aic.nrl.navy.mil  
**Citation:** 1993 IEEE Conference on Computer Vision and Pattern Recognition, 715-716, IEEE Computer Society Press  
**Date:** June 15-18, 1993  
**Report No.:** AIC-93-037

**Abstract**

The tripod operator is a class of feature extraction operators for computer-represented surfaces, such as range images. It facilitates the recognition and localization of objects by extracting a few sparse point samples in a regimented way, so that  $N$  sampled surface points yield only  $N-3$  independent scalar features containing ALL the surface shape information in these points and NO other information. They have complete six DOF isometry invariance. A tripod operator consists of three points in 3-space fixed at the vertices of an equilateral triangle and a procedure for making several "depth" measurements in the coordinate frame of the triangle, which is placed on the surface like a surveyor's tripod. Tripod operators can be used in many ways for the recognition and/or pose estimation of arbitrary surface shapes. Here we treat the rapid recognition of isolated objects in noisy range images using a statistical treatment of a few isolated tripod operators placements. The objects are initially preprocessed with tripod operators. The resulting feature vector sets are stored. Then new operator placements are made in an image containing an object to be recognized. Experiments show reliable recognition with only a few operator placements, despite significant noise.

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## NEURAL NETWORKS

**Title:** On Rejection of Unfamiliar Patterns with Multilayer Neural Networks

**Author(s):** Behrooz Kamgar-Parsi and Behzad Kamgar-Parsi

**E-mail Address:** kamgar@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-027

### Abstract

Most of the pattern recognition applications of multilayer neural networks have been concerned with classification and not rejection of a given pattern. For example, in character recognition all alphabetical characters must be recognized as one of the 26 characters, as there is nothing to reject. However, in many situations, there is no guarantee that all the patterns that will be presented to the network would actually belong to one of the classes on which the network has been trained. In such cases, a useful network must be capable of rejection as well as classification. In this paper we propose a scheme to develop multilayer networks with rejection capabilities.

---

**Title:** Integration of Detection and Classification of Signals Using Neural Networks

**Author(s):** Behrooz Kamgar-Parsi and Behzad Kamgar-Parsi

**E-mail Address:** kamgar@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** AIC-93-028

### Abstract

Many pattern recognition applications involving neural networks do not deal with detection as they do only classification. In these applications, either detection is not an issue or it is done prior to classification. Indeed, the same may be true for many of the conventional approaches where detection must be completed before recognition begins. In this paper, we propose a method for the integration of detection and classification using neural networks. The method is useful for situations where unambiguous detection of a pattern or signal is not possible, e.g. in situations where we are dealing with broken or overlapping signals or signals which cannot be isolated from the background.

---

**Title:** A Revised Clustering Technique Using a Hopfield Network

**Author(s):** Behrooz Kamgar-Parsi and Behzad Kamgar-Parsi

**E-mail Address:** kamgar@aic.nrl.navy.mil

**Citation:** World Congress on Neural Networks, Volume IV, 24-27, Lawrence Erlbaum Associates

**Date:** July 11-15, 1993

**Report No.:** AIC-93-030

### Abstract

Previously, Kamgar-Parsi *et al.* had developed an algorithm based on the Hopfield model for unsupervised clustering, or for forming self-organizing maps. Empirical results and comparisons with other techniques, including conventional techniques, have shown that the algorithm performs and scales well. Here we analyze the dynamical stability of the

network by examining the eigenmodes of the connection matrix. This reveals certain shortcomings of the original formulation and a way for correcting them, which leads to a revised formulation that further improves the effectiveness of the technique. This work also signifies the importance of analyzing the connection matrix eigenmodes in designing well-behaved, stable algorithms.

---

**Title:** The Seminal Hopfield-Tank Formulation of the Traveling Salesman Problem is Flawed

**Author(s):** Behzad Kamgar-Parsi and Behrooz Kamgar-Parsi

**E-mail Address:** kamgar@aic.nrl.navy.mil

**Citation:** Internal Report

**Date:** December 1993

**Report No.:** AIC-93-040

### **Abstract**

In neural optimization, it is essential that valid solutions be stable fixed points of the dynamics, otherwise the network will not converge to these solutions and cannot possibly find them. We prove that the original Hopfield-Tank (HT) formulation of the Traveling Salesman Problem is flawed, in that none of the valid tours are stable fixed points in the infinite gain limit. When the neuron gain is finite valid tours become only marginally stable. This helps explain the rather poor performance of the HT formulation in finding valid solutions. We also analyze the stability of several modified HT formulations, and show that some are indeed correct and effective. Empirical evidence are in agreement with our analytical results. The implication of this work is not that the Hopfield network is an inferior alternative for solving combinatorial optimizations. On the contrary, it shows that dynamical stability analysis is a tool that can help the Hopfield network realize its full potential, by identifying flaws in a heuristic formulation.

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**Title:** A High Fidelity Network Simulator for SDI  
**Author(s):** E. L. Althouse, D. N. McGregor, R. R. Nair, and S. G. Batsell  
**E-mail Address:** althouse@itd.nrl.navy.mil  
**Citation:** NRL Review: Naval Research Laboratory, Washington, D.C.  
**Date:** May 1993  
**Report No.:** CS-93-001

**Abstract**

A High Fidelity Network Simulator (HiFiNS) was developed to analyze the communication system performance for the proposed Strategic Defense Initiative (SDI) architecture. This architecture includes both the National Missile Defense First Site System (NMD FSS) and the Global Protection Against Limited Strikes (GPALS) strategic defense system. Such a simulation is necessary to verify that the envisioned strategic defense communication system will provide timely, secure, and reliable communications for surveillance, command and control, and weapons delivery to adequately perform its mission. The basic simulator is flexible enough to handle both ground- and space-based communication networks for SDI and is generally extensible to other large scale network applications.

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**Title:** An Approach to Voice Admission Control in Multihop Wireless Networks  
**Author(s):** C. M. Barnhart, J. E. Wieselthier, and A. Ephremides  
**E-mail Address:** barnhart@itd.nrl.navy.mil  
**Citation:** Proceedings of IEEE INFOCOM'93, 246-255, IEEE Society Press  
**Date:** March 1993  
**Report No.:** CS-93-002

**Abstract**

In this paper we investigate admission-control schemes for voice traffic in circuit-switched multihop radio networks. Our problem formulation is based on the recently introduced methodology of multiple-service, multiple-resource (MSMR) modeling under which we consider only those admission-control policies that yield a coordinate convex state space. This restriction, in conjunction with reasonable modeling assumptions, results in a product-form stationary distribution for the system state. We develop a recursive procedure to accelerate the evaluation of a large number of different admission-control policies, and a descent-search method to minimize the number of policies that must be evaluated in searching for the optimal one. The numerical examples we present indicate that performance improvement can be obtained by administering admission control, but this improvement is typically small unless different revenues or costs are associated with the various call types.

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**Title:** Improvement in Simulation Efficiency by Means of the Standard Clock: A Quantitative Study  
**Author(s):** C. M. Barnhart, J. E. Wieselthier, and A. Ephremides  
**E-mail Address:** barnhart@itd.nrl.navy.mil  
**Citation:** 32nd IEEE Conference on Decision and Control, San Antonio, TX  
**Date:** December 1993  
**Report No.:** CS-93-003

**Abstract**

In this paper we discuss the application of the Standard Clock (SC) approach to the simulation of a number of discrete-event dynamic systems (DEDS) examples, and demonstrate the improved efficiency that can be achieved by using this approach. First, we consider a single M/M/1/K queue, in which case we are interested in system performance

for many values of the parameter  $K$  (the buffer size). We then study networks of interconnected queues of this type. Finally, we consider the application of this technique to multihop circuit-switched voice communication networks.

Although the SC approach is ideally suited to parallel machines, performance improvement can also be achieved on a sequential computer, and our studies are based primarily on the use of such platforms. Our focus is on the improvement in simulation times that can be achieved, rather than on the performance results of the system being simulated. We quantify the time spent in the various aspects of the simulation, including random number generation and state updating, and compare predicted performance improvement with that which is actually measured.

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**Title:** Use of the Standard Clock to Improve Simulation Efficiency: A Quantitative Study Based on the M/M/1/K Queue

**Author(s):** C. M. Barnhart, J. E. Wieselthier, and A. Ephremides

**E-mail Address:** barnhart@itd.nrl.navy.mil

**Citation:** Proceedings of the 1993 Conference on Information Sciences and Systems  
Johns Hopkins University, 112-118

**Date:** March 1993

**Report No.:** CS-93-004

#### **Abstract**

In this paper we discuss the application of the Standard Clock (SC) approach to discrete-event dynamic systems (DEDS) examples involving the M/M/1/K queue, and demonstrate the improved efficiency that can be achieved using this approach. We are interested in system performance for many values of the parameter  $K$  (the buffer size). In addition to the study of a single M/M/1/K queue, we study networks of interconnected queues of this type.

Although the SC approach is ideally suited to parallel machines, performance improvement can also be achieved on a sequential computer, and our studies are based primarily on the use of such platforms. Our focus is on the improvement in simulation times that can be achieved, rather than on the performance results of the system being simulated. We quantify the time spent in the various aspects of the simulation, including random number generation and state updating, and compare predicted performance improvement with that which is actually measured. Also, we make observations on the types of problems that are expected to benefit most from the SC approach.

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**Title:** Admission Control In Integrated Voice/Data Multihop Radio Networks

**Author(s):** C. M. Barnhart, J. E. Wieselthier, and A. Ephremides

**E-mail Address:** barnhart@itd.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/5521—93-7196

**Date:** January 1993

**Report No.:** CS-93-005

#### **Abstract**

In this report, we investigate the admission control problem for voice traffic in integrated multihop radio networks. We consider only those admission control policies that yield a "coordinate convex" state space. This restriction, in conjunction with the use of a "blocked-calls-cleared" mode of operation and the assumption that the voice process is Markovian, results in a product-form stationary distribution for the voice state of the system. The product-form distribution allows the straightforward evaluation of network performance when subject to different admission control policies.

A large number of coordinate convex admission-control policies must be searched to determine the optimal policy. We develop a recursive procedure to speed the evaluation

of a large number of different policies, as well as descent-search method to reduce significantly the number of policies that must be evaluated in searching for the optimal one. The numerical examples we present indicate that improved performance can be obtained by administering admission control, but this improvement is typically small unless different revenues or costs are associated with the various call types.

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**Title:** A Neural Network Approach to Solving the Link Activation Problem in Multihop Radio Networks

**Author(s):** C. M. Barnhart, J. E. Wieselthier, and A. Ephremides

**E-mail Address:** barnhart@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** April 1993

**Report No.:** CS-93-006

**Abstract**

We address the problem of "link activation" or "scheduling" in multihop packet radio networks. The objective is to determine a conflict-free schedule of minimum length that satisfies the specified end-to-end communication requirements. It is well known that this problem, in almost all of its forms, is a combinatorial-optimization problem of high complexity. We approach this problem by the use of a Hopfield neural network model in which the method of Lagrange multipliers is used to vary dynamically the values of the coefficients used in the connection weights.

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**Title:** DC HULLCOM, Improvements in Shipboard Acoustical Communications:

Adaptive Equalization

**Author(s):** S. Batsell, D. Arango, T. Pham, and T. Street

**E-mail Address:** batsell@itd.nrl.navy.mil

**Citation:** NRL/MR/6180--93-7330

**Date:** October 1993

**Report No.:** CS-93-007

**Abstract**

This report discusses the use of adaptive equalization to reduce the effects of frequency-selective fading due to multipath in the acoustical communication channel of the DC HULLCOM system. The constant modulus algorithm (CMA) was chosen for this purpose. CMA is a blind equalization technique that partially restores the waveform by forcing the complex signal modulus to a constant value. The technique is applied to actual ship data from the USS Barry and the results presented.

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**Title:** HiFiNS: An Object-Oriented Simulation of Large-Scale Communication Networks

**Author(s):** S. G. Batsell, D. N. McGregor, R. R. Nair, and E. L. Althouse

**E-mail Address:** batsell@itd.nrl.navy.mil

**Citation:** IEEE MILCOM'93

**Date:** October 1993

**Report No.:** CS-93-008

**Abstract**

A High Fidelity Network Simulator (HiFiNS) is being developed by the Naval Research Laboratory. This simulator is being developed using an object-oriented design to provide maximum flexibility in simulating a wide variety of network topologies, protocols, network algorithms, and operational scenarios. The simulator can interface with element models (e.g., radars, weapon systems, and space sensors), a network manager, and an

interactive graphical user interface that will control the system from pre-processing to post-processing data analysis. The simulation is designed to operate in a distributed mode over a cluster of workstations using shared memory communications to improve computational throughput. The simulator provides an excellent platform to explore end-to-end system performance, design tradeoffs, and to optimize algorithms for use in operational large-scale networks.

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**Title:** Analysis of a Threshold Priority Queuing System with Applications to ATM

**Author(s):** A. Battou (Locus, Inc.) and G. Nguyen

**E-mail Address:** [nguyen@itd.nrl.navy.mil](mailto:nguyen@itd.nrl.navy.mil)

**Citation:** IEEE/ACM Transactions on Networking

**Date:** 1993

**Report No.:** CS-93-009

#### **Abstract**

A queuing model with two finite-size buffers, a single constant rate server using a serving strategy based on buffer thresholds is studied. Exact relationships for buffer size, overflow probabilities, and queuing delay are obtained. The queuing model is very general, and an application in ATM switching is described. The results are presented in graphs that are useful in selecting a threshold pair that satisfies certain constraints on delay and cell loss.

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**Title:** Strategic Engagement Planning Using a High Fidelity Network Simulation

**Author(s):** J. Carder, S. Mallder, and S. Butler (Booz•Allen & Hamilton, Inc.)

**E-mail Address:** [mgregor@itd.nrl.navy.mil](mailto:mgregor@itd.nrl.navy.mil)

**Citation:** IEEE MILCOM'93

**Date:** October 1993

**Report No.:** CS-93-010

#### **Abstract**

High Fidelity Network Simulation (HiFiNS) is used to evaluate and validate proposed C<sup>3</sup> architectures for Ballistic Missile Defense. It is a comprehensive, non-real-time, end-to-end communication network simulator. HiFiNS models National Missile Defense system elements -- Ground Based Radar (GBR), Ground Based Interceptors (GBI), Brilliant Eyes (BE), and Command and Control Element (C<sup>2</sup>E). These systems utilize communication network simulation to convey data during battle.

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**Title:** Perturbation Analysis and 'Rapid Learning' in the Control of Manufacturing Systems

**Author(s):** C. G. Cassandras (University of Massachusetts, Amherst)

**E-mail Address:** [wieselthier@itd.nrl.navy.mil](mailto:wieselthier@itd.nrl.navy.mil)

**Citation:** Control and Dynamic Systems, C.T. Leondes, editor, Academic Press

**Date:** 1993

**Report No.:** CS-93-011

#### **Abstract**

We review a family of techniques known as Perturbation Analysis (PA), which allow us to estimate sensitivities of performance measures of discrete event dynamic systems (DEDS) with respect to various parameters of interest, which may be continuous or discrete. We concentrate on discrete parameters, which in many cases are particularly crucial in the behavior of a manufacturing system as we illustrate through some examples. Given a set of such parameters or control actions  $\{u_1, \dots, u_m\}$ , the objective of the "rapid learning" framework is the following: observe the system under some such control action,

e.g.,  $u_1$ , and estimate its performance under all possible  $u_1, \dots, u_m$  in parallel. We describe two specific techniques that can meet this objective in fairly general settings, and provide examples of applications.

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**Title:** 'Rapid Learning' Techniques for Discrete Event Systems: Some Recent Results and Applications to Traffic Smoothing

**Author(s):** C. G. Cassandras (University of Massachusetts, Amherst)

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Proceedings of the 1993 IFAC World Congress, v III, 323-326

**Date:** August 1993

**Report No.:** CS-93-012

#### **Abstract**

Motivated by recent advances in "rapid learning" techniques for Discrete Event Systems (DES), we present a unified framework based on the fundamental *sample path constructability* problem: for a finite discrete parameter set  $\Theta = \{\theta_1, \dots, \theta_m\}$ , given a sample path under  $\theta_1$ , the problem is to simultaneously construct sample paths under all remaining parameter values. We review and compare two approaches for the solution of this problem, the *Standard Clock* (SC) approach and *Augmented Systems Analysis* (ASA). Next, we present a new area of potential use of the ASA approach: smoothing arbitrary, highly bursty, and possibly nonstationary traffic processes which are encountered in many applications. This problem has become critical in the effort to develop flow control techniques for integrated-service, high-speed networks. We show how ASA can be used to (a) derive some basic structural properties of a simple smoothing scheme known as the "Leaky Bucket" mechanism through very simple means and under very general conditions, and, more importantly in practice, (b) control a parameter of the scheme *on line* in order to achieve typical design objectives such as minimizing variability of the traffic process without exceeding tolerable delays or blocking effects.

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**Title:** Optimal Scheduling in Systems with Delay-Sensitive Traffic

**Author(s):** C. G. Cassandras and V. Julka (University of Massachusetts, Amherst)

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** 32nd IEEE Conference on Decision and Control, San Antonio, TX

**Date:** December 1993

**Report No.:** CS-93-013

#### **Abstract**

We consider scheduling problems where a resource must provide service to a set of  $M$  distinct customer classes. Customers belong to one of  $N$  arrival streams, where  $N \neq M$  in general. In contrast to earlier work, we consider delay-sensitive customers who cannot be queued for more than  $n$  time slots, where  $n$  is fixed. Thus, upon arrival, a customer is either accepted if this constraint can be satisfied, or it is *blocked*. The objective then is to determine a scheduling policy that minimizes the probability that a customer is blocked. This feature necessitates the use of a cyclic scheduling policy, such that each class is always visited within  $n$  time slots. Thus, the problem becomes one of allocating the slots of an  $n$ -slot *frame* to  $N$  classes. This is a generally hard discrete optimization problem. We propose an approach which transforms this problem into a continuous optimization one. We develop a gradient-based algorithm and derive unbiased gradient estimators required for the on-line solution of the latter problem under two different models of customer blocking.

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**Title:** A New Approach for Some Combinatorially Hard Stochastic Optimization Problems  
**Author(s):** C. G. Cassandras and V. Julka (University of Massachusetts, Amherst)  
**E-mail Address:** wieselthier@itd.nrl.navy.mil  
**Citation:** Proceedings of the Thirty-first Annual Allerton Conference on Communication, Control, and Computing  
**Date:** September-October 1993  
**Report No.:** CS-93-014

**Abstract**

We present a new approach for solving a class of combinatorially hard stochastic optimization problems encountered in the design and control of discrete-event systems. The main idea of the approach is to transform the original discrete optimization problem into an auxiliary continuous optimization problem through an appropriate randomization mechanism and then solve the new problem using gradient-based techniques and Smoothed Perturbation Analysis (SPA) to estimate performance gradients from a single observed sample path. Mapping back to the original discrete decision space yields the optimal solution in that space.

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**Title:** Marked/Phantom Slot Algorithms for a Class of Scheduling Problems  
**Author(s):** C. G. Cassandras and V. Julka (University of Massachusetts)  
**E-mail Address:** wieselthier@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** CS-93-015

**Abstract**

We address the problem of scheduling  $M$  customer classes in a single-server system, with customers arriving in one of  $N$  arrival streams, as it arises in scheduling transmissions in packet radio networks. In general,  $N \neq M$  and a customer from some stream may join one of several classes. We consider a slotted time model where at each scheduling epoch the server is assigned to a particular class and can serve multiple customers simultaneously, one from every arrival stream that can belong to this class. The assignment is based on a *random polling* policy: the current time slot is allocated to the  $i$ th class with probability  $q_i$ . Our objective is to determine the optimal probabilities by adjusting them on line so as to optimize some overall performance measure. We present an approach based on perturbation analysis techniques, where all customer arrival processes can be arbitrary, and so no information about them is required. The basis of this approach is the development of two sensitivity estimators leading to a *Marked Slot* and a *Phantom Slot* algorithm. The algorithms determine the effect of removing/adding service slots to an existing schedule on the mean customer waiting times by directly observing the system. The optimal slot assignment probabilities are then used to design a *deterministic* scheduling policy based on the Golden Ratio policy. Finally, several numerical results based on a simple optimization algorithm are included.

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**Title:** Control of Integrated Voice/Data Multi-Hop Radio Networks Via Reduced-Load Approximations

**Author(s):** E. Geraniotis and I.-H. Lin (Locus, Inc. and University of Maryland)

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/5521-93-7390

**Date:** September 1993

**Report No.:** CS-93-016

**Abstract**

In this report we develop reduced-load approximation techniques based on the stochastic knapsack and the Pascal distribution, which enable the computationally efficient and accurate evaluation of the probability of voice blocking, the probability of data queuing, and the average data delay in integrated voice/data multi-hop radio networks. Monte-Carlo summation techniques are also used to verify the accuracy of the approximations. The reduced-load approximations exhibit excellent to very satisfactory accuracy for the entire range of network and traffic parameters of interest, while the computational effort necessary for their evaluation is substantially lower than that of the exact expressions (which is actually prohibitive for multi-hop radio networks of even moderate size). They are also used successfully to approximate the derivatives (sensitivities) of the above performance measures with respect to network and traffic parameters. These approximations are applicable to single-rate and multi-rate voice models, as well as to models with voice activity and silence periods. Besides the accurate and time-efficient performance evaluation of integrated voice/data multi-hop radio networks, the computational efficiency and the accuracy of these approximations enables their use for control and optimization purposes.

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**Title:** Admission Control for Integrated Voice/Data Multi-Hop Radio Networks Via Reduced-Load Approximations

**Author(s):** E. Geraniotis and I.-H. Lin (Locus, Inc. and University of Maryland)

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** CS-93-017

**Abstract**

In this paper we develop reduced-load approximation techniques for evaluating accurately and efficiently the probability of voice blocking, the probability of data queuing, and the average data delay in integrated voice/data multi-hop radio networks for which the main resource are the transceivers at the nodes. These approximation techniques are based on the stochastic knapsack and the Pascal distribution which for single-rate networks result in identical expressions for the approximations to the above performance measures. Monte-Carlo summation techniques are also used to verify the accuracy of the approximations. The approximations are derived for networks without any admission control as well as for networks which admit voice calls based on threshold policies. The accuracy and computational efficiency of the approximations are very satisfactory for a broad range of network and traffic parameters and enables their use for selecting in a near-optimal manner the thresholds of the admission control policies.

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**Title:** Parallel Computation in the Design and Stochastic Optimization of Discrete Event Systems

**Author(s):** Y. C. Ho (Harvard) and C. G. Cassandras (University of Massachusetts)

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** 32nd IEEE Conference on Decision and Control (Invited), San Antonio, TX

**Date:** December 1993

**Report No.:** CS-93-018

**Abstract**

This paper overviews the issue of constructing multiple sample paths of a stochastic Discrete Event Dynamic System (DEDS) under changes in some parameter value or its actual structure in the context of parallel processing. The basic sample path constructability problem is formulated and some recent solution techniques are reviewed. Assuming that the ultimate objective of this parallelized sample path construction is to select good designs and to make good decisions, and, ultimately, to optimize the performance of a DEDS, we also outline the issues involved in using parallel computation for this purpose and describe some recently proposed techniques based on "ordinal" optimization.

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**Title:** High-Fidelity Protocol Modeling Issues in Large-Scale Network Simulations

**Author(s):** M. R. McDonald, J. B. Cain, J. W. Nieto, and K. Edwards (Harris Corp.)

**E-mail Address:** mcgregor@itd.nrl.navy.mil

**Citation:** IEEE MILCOM'93

**Date:** October 1993

**Report No.:** CS-93-019

**Abstract**

This paper examines issues relating to the construction of high-fidelity models of network protocols and their associated hardware to be used in large-scale network simulations. Some issues addressed include: fidelity trade-offs, layering of node models, detailed layer models, fidelity of the protocol model, and modeling of hardware constraints. The modeling mechanisms used in a recently developed simulation to model the various delays and capacity limitations will be used as examples.

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**Title:** Simulation of Large-Scale Strategic Communication Networks

**Author(s):** D. N. McGregor, R. R. Nair, S. G. Batsell and E. L. Althouse

**E-mail Address:** mcgregor@itd.nrl.navy.mil

**Citation:** SCS 1993 Summer Computer Simulation Conference

**Date:** July 1993

**Report No.:** CS-93-020

**Abstract**

A discrete-event High Fidelity Network Simulator (HiFiNS) has been developed in order to analyze the communication system performance for the proposed Strategic Defense Initiative (SDI) architecture. This architecture includes both the National Missile Defense (NMD) and the Global Protection Against Limited Strikes (GPALS) strategic defense systems. Such a simulation is necessary to verify that the envisioned strategic defense communication system will provide timely, secure, and reliable communications for surveillance, command and control, and weapons delivery to adequately perform its mission. The basic simulator is flexible enough to handle both ground- and space-based

communication networks for SDI and is generally extensible to other large scale network applications. It provides the tools and experimental environment to perform communication network sensitivity and robustness tradeoff studies. The simulator can also be used to estimate system responses which depend on the threat, network management design and resulting connectivity, and message delivery times.

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**Title:** Efficient Algorithms for Performing Packet Broadcasts in a Mesh Network

**Author(s):** E. Modiano and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** CS-93-021

**Abstract**

We consider processors communicating over a mesh network with the objective of broadcasting information amongst each other. One instance of the problem involves a number of nodes all with the same message to be broadcasted. For that problem a lower-bound on the time to complete the broadcast, and an algorithm which achieves this bound are presented. In another instance, every node in the mesh has packets to be broadcast arriving independently, according to a Poisson random process. The stability region for performing such broadcasts is characterized, and broadcast algorithms which operate efficiently within that region are presented. These algorithms involve interacting queues whose analysis is known to be very difficult. Toward that end we develop an approximation which models an  $n$ -dimensional infinite Markov chain as a single dimensional infinite Markov chain together with an  $n$ -dimensional finite Markov chain. This approximate model can be analyzed and the results compare favorably with simulation.

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**Title:** An Approach for the Analysis of Packet Delay in an Integrated Mobile Radio Network

**Author(s):** E. Modiano, J. E. Wieselthier, and A. Ephremides

**E-mail Address:** modiano@itd.nrl.navy.mil

**Citation:** Proceedings of the 1993 Conference on Information Sciences and Systems, Johns Hopkins University, 138

**Date:** March 1993

**Report No.:** CS-93-022

**Abstract**

We consider a simple network model for the study of the Voice and Data integration problem. Our objective is to allocate network resources to minimize a performance measure that is a linear combination of voice call blocking probability and packet delay. Toward that end we develop an approximate model for the analysis of packet delay. This model exploits the "regular" nature of data traffic when packet length is fixed by modeling the output of each intermediate network link as a Bernoulli random variable with a parameter equal to the arrival rate at that link. We show that this model can be used to approximate networks of arbitrary topology with various link capacities. We compare the approximation with simulation for a number of network topologies, and show that the approximation compares very well with simulation, especially for large networks.

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**Title:** A Model for the Approximation of Interacting Queues that Arise in Multiple Access Schemes

**Author(s):** E. Modiano and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Proceedings of the 1993 IEEE International Symposium on Information Theory, 324

**Date:** January 1993

**Report No.:** CS-93-023

**Abstract**

We develop an approximate model for analyzing interacting queues. This new approximation models an N-dimensional infinite Markov chain by means of two Markov chains, one being one-dimensional and infinite and the other being N-dimensional and finite. The transition probabilities of each chain are expressed in terms of statistics of the other chain. The two chains can be solved together using standard iterative methods to yield an approximation to the original N-dimensional infinite chain. This new model is a refinement of previous models that have been used to analyze interacting queues.

We use this approximate model to analyze systems of dependent queues which often arise in multiple access protocols. We begin by applying this approximation to the analysis of a multiple-node broadcast algorithm for a mesh network which was proposed in a previous paper by the authors. The results of our approximation compare very well with simulation and offer a substantial improvement over existing approximations. We then show how this model can also be used to analyze the ALOHA multiple access protocol.

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**Title:** A Method for Delay Analysis of Interacting Queues in Multiple Access Systems

**Author(s):** E. Modiano and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Proceedings of IEEE INFOCOM'93, 447-454

**Date:** March 1993

**Report No.:** CS-93-024

**Abstract**

We develop an approximate model for analyzing interacting queues. This new approximation models an N-dimensional infinite Markov chain by means of two Markov chains, one being one-dimensional and infinite and the other being N-dimensional and finite. The transition probabilities of each chain are expressed in terms of statistics of the other chain. The two chains can be solved together using standard iterative methods to yield an approximation to the original N-dimensional infinite chain. We use this approximate model to analyze systems of dependent queues which often arise in multiple access protocols. We show how this model can be used to analyze the ALOHA multiple access protocol as well as a multiple-node broadcast algorithm for a mesh network which was proposed in a previous paper by the authors. The results of our approximation compare very well with simulation.

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**Title:** A Simple Analysis of Queuing Delay in a Tree Network of Discrete-Time Queues with Constant Service Time

**Author(s):** E. Modiano, J. E. Wieselthier, and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** CS-93-025

**Abstract**

We consider a network of discrete-time queues with constant service time for the purpose of analyzing the delay in a packet-switched data network with fixed-length packets. We begin by considering a simple tandem of queues, and obtain an exact solution for the delay through the tandem. We then extend our result to a concentrating tree network of queues. Our solution is based on considering an equivalent network, in which at each node packets in transit are given priority over exogenous arrivals. The solution to the equivalent model is easily computed, from which the solution to the original model can be obtained.

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**Title:** Reliability Analysis for FDDI Dual Homing Networks

**Author(s):** G. D. Nguyen

**E-mail Address:** nguyen@itd.nrl.navy.mil

**Citation:** IEEE 18th Conference on Local Computer Networks, 140-146

**Date:** September 1993

**Report No.:** CS-93-026

**Abstract**

Closed-form reliability functions for the well-known dual homing configuration for the Fiber Distributed Data Interface (FDDI) are derived by the familiar combinatorial method. The new reliability functions are then compared to that of the dual ring configuration via numerical examples, which again show that in most case the dual homing network is more reliable than the ring network; however, the model analysis also shows that dual homing is recommended only if certain network parameter constraints are met.

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**Title:** Reliability Analysis for FDDI Dual Homing Networks

**Author(s):** G. D. Nguyen

**E-mail Address:** nguyen@itd.nrl.navy.mil

**Citation:** NRL Report NRL/FR/5862--93-9552

**Date:** May 1993

**Report No.:** CS-93-027

**Abstract**

Closed-form reliability functions for the well-known dual homing configuration for the Fiber Distributed Data Interface (FDDI) are derived by the familiar combinatorial method. The new reliability functions are then compared to that of the dual ring configuration via numerical examples, which again show that in most case the dual homing network is more reliable than the ring network. Further extension of the new results is also discussed.

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**Title:** DC HULLCOM, Improvements in Shipboard Acoustical Communications: Channel Modeling and Modulation Techniques  
**Author(s):** T. T. Street, S. G. Batsell, D. A. Arango, T. V. Pham, T. J. Aberle, J. Vodzak, V. A. Rohrbaugh, and G. W. Wayne  
**E-mail Address:** batsell@itd.nrl.navy.mil  
**Citation:** NRL/MR/6182--93-6888  
**Date:** March 1993  
**Report No.:** CS-93-028

**Abstract**

An analysis was made of the system requirements for the DC Hullcom shipboard acoustical communication system, including the type of format (digital or analog) and bandwidth. As part of this effort, the properties of the acoustical channel were measured and then modeled. It was found that the multipath effects were the principal difficulty in channel propagation as multipath caused the channel to be highly frequency-selective thereby allowing only certain frequencies to propagate. Using this information, several noncoherent modulation techniques, including Frequency Shift Keying (FSK), Minimum shift keying (MSK), and spread spectrum methods were evaluated and then tested on board the USS Barry. Experiments showing that MSK was the least affected by the channel. Having determined the best modulation scheme additional signal processing techniques that would complement MSK in reducing the multipath effects were analyzed, including adaptive equalization and coding. While the channel suffers from frequency-selective multipath effects, the use of MSK combined with adaptive equalization and coding will greatly reduce the channel effects.

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**Title:** A Multi-Channel Architecture for Naval Task Force Communication  
**Author(s):** W. A. Thoet (Booz•Allen & Hamilton, Inc.), D. J. Baker, and D. N. McGregor  
**E-mail Address:** baker@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** CS-93-029

**Abstract**

This paper describes a new architecture for mobile, narrowband, broadcast radio networks, which is called the Multi-Channel Architecture (MCA). We compare the performance limits of an MCA network to a single-channel architecture based on an Ideal Handoff Assigned Multiple Access (IHAMA) protocol. Both architectures have been proposed for Naval intratask force communications with HF and line-of-sight UHF radio. Formulas for the network load capacity for each architecture are derived for several important cases, and simulation results are presented for those cases where analytical results are not available. Based on "equivalent" equipment, the load capacity of MCA is shown to exceed that of IHAMA. MCA also outperformed IHAMA in other performance areas such as delay, the ability to handle voice and virtual circuits and jam resistance.

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**Title:** Efficient Simulation of DEDS by Means of Standard Clock Techniques: Queuing and Integrated Radio Network Examples

**Author(s):** J. E. Wieselthier, C. M. Barnhart, and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/5521--93-7392

**Date:** September 1993

**Report No.:** CS-93-030

**Abstract**

In this report we discuss the application of the Standard Clock (SC) approach to the simulation of several examples of discrete-event dynamic systems (DEDS), and demonstrate the improved efficiency that can be achieved by using this approach. In SC simulation, a common clock (event time, event type) sequence is used by a large number of simulations running in parallel, thereby resulting in a significant decrease in the most costly aspect of the simulation process, namely the generation of events. In studies of the M/M/1/K queue, we quantify the time spent in the various aspects of the simulation, and compare predicted performance improvement with that which is actually measured. This approach scales well when applied to larger problems, including queuing networks and multihop radio networks.

We develop a SC simulation model for a multihop, integrated voice/data radio network, and demonstrate its use for the determination of admission control policies. Ordinal optimization techniques are shown to provide good, although not optimal, control policies on the basis of short simulation runs.

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**Title:** Performance Analysis of Fixed- and Movable-Boundary Channel-Access Schemes for Integrated Voice/Data Wireless Networks

**Author(s):** J. E. Wieselthier and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Proceedings of IEEE INFOCOM'93, 1204-1213

**Date:** March 1993

**Report No.:** CS-93-031

**Abstract**

In this paper we present a performance analysis of the Wireless Integrated Multiple Access (WIMA) protocol, which is well suited to either satellite or to terrestrial networks. A two-dimensional first-order Markov chain model for this scheme is presented, and techniques that exploit the structural properties of this chain to simplify the evaluation of the equilibrium state, without sacrificing accuracy, are described. Analytical models for the evaluation of data-packet delay for both fixed- and movable-boundary versions of this protocol and for voice-call blocking probability are presented. Performance results illustrate the dependence of performance on system parameters, and demonstrate the improved performance that can be achieved through the use of the movable-boundary version.

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**Title:** Ordinal Optimization of Admission Control in Wireless Multihop Voice/Data Networks Via Standard Clock Simulation  
**Author(s):** J. E. Wieselthier, C. M. Barnhart, and A. Ephremides  
**E-mail Address:** wieselthier@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** September 1993  
**Report No.:** CS-93-032

**Abstract**

In this paper we study the voice-call admission-control problem in integrated voice/data multihop radio networks, in which performance measures include voice-call blocking probability and data-packet delay. We develop an efficient simulation model based on the use of the Standard Clock (SC) approach, which permits the simultaneous simulation of a large number of admission-control policies, thereby reducing computation time significantly. We then demonstrate the effectiveness of ordinal-optimization techniques, which provide a remarkably good ranking of admission-control policies after relatively short simulation runs, thereby facilitating the rapid determination of good policies. Moreover, we demonstrate that the use of crude and inaccurate analytical and simulation models can provide highly accurate policy rankings that can be used in conjunction with ordinal-optimization methods, provided that they incorporate the key aspects of system operation. Once a small set of candidate policies is selected, accurate performance estimates and improved rankings can be obtained by means of SC simulation.

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**Title:** A Neural Network Approach To Routing Without Interference In Multihop Radio Networks  
**Author(s):** J. E. Wieselthier, C. M. Barnhart, and A. Ephremides  
**E-mail Address:** wieselthier@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** CS-93-033

**Abstract**

Although the issues of routing and of scheduling the activation of links in packet radio networks are highly interdependent, few studies have addressed their interactions. In this paper, we address a form of the problem of routing for the minimization of congestion as a first step toward the solution of the joint routing-scheduling problem. We formulate this as a combinatorial-optimization problem, and we develop a Hopfield neural network (NN) model for its solution. The determination of the coefficients in the connection weights is the most critical issue in the design and simulation of Hopfield NN models. In our studies, we use the method of Lagrange multipliers, which permits these coefficients to vary dynamically along with the evolution of the system state. Extensive software simulation results demonstrate the capability of our approach to determine good sets of routes in large, heavily-congested networks.

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**Title:** Fixed- And Movable-Boundary Channel-Access Schemes For Integrated Voice/Data Wireless Networks  
**Author(s):** J. E. Wieselthier and A. Ephremides  
**E-mail Address:** wieselthier@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** CS-93-034

**Abstract**

In this paper we address the major issues associated with channel access in integrated wireless networks, and we propose and analyze the Wireless Integrated Multiple Access (WIMA) protocol. This scheme is based on a mixture of boundary ideas for integration and of previously introduced protocols for wireless access, and is well suited to either satellite or to terrestrial networks. A two-dimensional first-order Markov chain model for this scheme is presented, and techniques that exploit the structural properties of this chain to simplify the evaluation of the equilibrium state, without sacrificing accuracy, are described. Analytical models for the evaluation of data-packet delay for both fixed- and movable-boundary versions of this protocol and for voice-call blocking probability are presented. Performance results illustrate the dependence of performance on system parameters, and demonstrate the improved performance that can be achieved through the use of the movable-boundary version.

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**Title:** On the Problems of Data-Delay Evaluation and Minimization in Integrated Voice/Data Networks  
**Author(s):** J. E. Wieselthier, C. M. Barnhart, and A. Ephremides  
**E-mail Address:** wieselthier@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** 1993  
**Report No.:** CS-93-035

**Abstract**

We approach the data-delay problem in integrated networks from two distinct viewpoints. In the first we propose an extremely simple method, which yields inaccurate data-delay estimates. However, these estimates preserve (nearly exactly) the ranking of the actual delay values for different voice admission-control policies. Thus, it is possible to perform "ordinal optimization" to determine some of the best policies, without actually obtaining a good estimate of their performance. In the second we address issues related to the development of accurate delay models for integrated networks. A major obstacle to the development of such models has been the lack of an accurate model to characterize the time-varying nature of voice traffic in multihop integrated voice/data networks. Our starting point in both cases is the use of the product-form solution to characterize the state of the voice-call process in the network. In our ordinal-optimization studies, we make the approximation that the quantity of resources available for data traffic is constant and equal to the expected "residual capacity" (the expected capacity not used by voice). Then, as a step toward the development of accurate delay models, we develop approximate models that characterize the time-varying behavior of the voice-call process for both wireline and wireless networks.

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**Title:** A Channel Simulation Processor for the Multi-Node Tactical Network Simulator  
**Author(s):** Joseph P. Macker  
**E-mail Address:** macker@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report NRL/MR/5523--93-7184  
**Date:** January 17, 1993  
**Report No.:** CS-93-036

**Abstract**

The design and development of a digital signal processor (DSP) based groundwave and ionospheric communication channel simulator is described. The primary objective is to simulate communication channel perturbations for a network of communication links via an array of DSP modules operating in real-time. This array of channel simulator processors is a subsystem of the multi-node tactical network simulator (TACNETSIM) being developed by the Information Technology Division at the Naval Research Laboratory (NRL). The propagation model developed is based upon intra-battlegroup high frequency (HF) communications. The communication channel model consists of two modes of propagation: HF groundwave and HF skywave. The HF skywave component is simulated via a Watterson ionospheric model. The real-time DSP implementation of the Watterson ionospheric model is described in terms of its subprocesses. The performance of each subprocess is shown to be within established statistical parameters. Detailed specifications are given of both the hardware and software design. The simulator is designed for dynamic channel modeling and includes a data interface for real-time program control.

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**Title:** Admission-Control Policies for Integrated Communication Networks  
**Author(s):** C. M. Barnhart, J. E. Wieselthier, and A. Ephremides  
**E-mail Address:** barnhart@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** November 1993  
**Report No.:** CS-93-037

**Abstract**

In this paper, we investigate the admission-control problem for voice traffic in integrated multihop radio networks. We consider only those admission-control policies that yield a "coordinate-convex" state space. This restriction, in conjunction with the use of a "blocked-calls-cleared" mode of operation and the usual assumptions on the voice process statistics, results in a product-form stationary distribution for the voice state of the system. The product-form distribution allows the straightforward evaluation of network performance when subject to different admission-control policies.

A large number of coordinate-convex admission-control policies must be searched to determine the optimal policy. We develop a recursive procedure to speed the evaluation of a large number of different policies, and a descent-search method to reduce significantly the number of policies that must be evaluated in searching for the optimal one. The numerical examples we present indicate that reduced blocking probability (or increased throughput) can be obtained by administering admission control, but this improvement is typically small because networks tend to be self regulating. However, considerable improvement can be obtained when the performance measure associates different revenues or costs with the various call types.

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**Title:** Modeling, Performance Evaluation, and Ordinal Optimization of Integrated Voice/Data Networks

**Author(s):** J. E. Wieselthier, C. M. Barnhart, and A. Ephremides

**E-mail Address:** wieselthier@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** CS-93-038

**Abstract**

The evaluation of data-packet delay in integrated networks is a difficult problem because the quantity of network resources available for data traffic is time varying and dependent on the voice traffic. In this paper we demonstrate that an extremely simple model for data-packet delay, although inaccurate in terms of delay measurements, can provide a remarkably accurate ranking among a number of different control policies. We also address the issues associated with the development of accurate delay models, and develop a simplified model for voice traffic in wireless networks that provides a highly accurate characterization of the time-varying resources used by voice, and hence available for data.

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**Title:** SG-1157/U Digital Processing Clock Operations and Maintenance Manual

**Author(s):** T. H. Gattis, J. J. O'Neill, and J. A. Bowman

**E-mail Address:** gattis@itd.nrl.navy.mil

**Citation:** NRL/MR/5524--93-7383

**Date:** September 3, 1993

**Report No.:** CS-93-039

**Abstract**

The Model SG-1157/U Digital Processing Clock, and Model ID-2170/U, Remote Time Readout, equipments are used on all SSN 688 class submarines for generation of precise timing signals and display of the time-of-day information. The SG-1157/U operates with an external standard such as the 0-169/U or 0-1824/U Cesium Beam Frequency Standard or from its own internal oscillator when a reference standard is not available. Several timing signal outputs are provided, such as 1 pps, 1 pp10s, time of event, parallel time code and the XR-3 serial time code. The SG-1157/U is capable of simultaneously driving four ID-2170/U Remote Time Readouts and one XR-3 time code display. Details of a redesigned 2137 Time Code Generator board are provided. The redesigned board is referred to as a B Series A8 Circuit Board. This board provides added circuit drive capability and replaces expensive or difficult to obtain parts. Internal batteries are provided to permit continuous operation for up to thirty (30) minutes during alternating current (AC) power interruptions.

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**Title:** An Integrated Knowledge Acquisition and Database Management System

**Author(s):** J. A. Molnar and C. Barclay

**E-mail Address:** molnar@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** CS-93-040

**Abstract**

FISDM was a menu driven database interface that was developed to enhance the acquisition and management of knowledge acquired for Fault Isolation System Knowledge Bases. This software was general purpose and could be accessed on any ASCII terminal. FISDMPRO enhanced the basic FISDM software by providing a Graphical User Interface

(GUI) and expert system to aid knowledge base creation. FISDMPRO was developed with the GUI development tool TAE (Transportable Application Engine). The Expert system portion of FISDMPRO uses the CLIPS expert system engine and rules were developed that govern the creation of the major components of a FIS knowledge base. The Interface now presents a graphical method of creating the knowledge base by simply defining modules as blocks and providing interconnections between the blocks. The interconnections are governed by the physical interrelations of the modules, and the expert system generates rules relating to the interconnections. A presentation of the capabilities is presented along with the discussion of the software dynamics.

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**Title:** Functional, Electrical, and Mechanical Description of the W-Band Noise Measurement System and the NRL W-Band VXI Module

**Author(s):** J. A. Molnar and T. V. Mai

**E-mail Address:** molnar@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** 1993

**Report No.:** CS-93-041

**Abstract:**

A Millimeter Wave measurement system was developed. The system provided the general capabilities of signal generation at W-Band (75-110 GHz). The signal generator level is controllable and can be leveled to a single level across the frequency band. Modulation (AM, FM and Pulse) is built into the signal generator. The system also incorporates downconversion circuitry that is used in noise measurements and in signal analysis. The system is integrated in a VXI mainframe and a PC is used as the system controller. This paper discussed the architecture of the system and provides details on the mechanical and electrical hardware. Software was developed to demonstrate the general capability of the system. The software uses the Windows operating system and provides a graphical front end to the system. The performance of the system is presented.

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**Title:** VXI Implementation of a Millimeter Wave Measurement System

**Author(s):** J. A. Molnar and T. V. Mai

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**Citation:** Instrumentation and Measurement Technology Conference, May 1993

**Date:** May 1993

**Report No.:** CS-93-042

**Abstract:**

Development of systems employing millimeter wave technology is increasing as system designers exploit their advantages over lower frequency microwaves. Testing of these systems is essential to ensure proper operation. A measurement system for the W-band frequency range (75 - 110 GHz) was developed. The system includes an instrument controller and three other instruments that are inserted into a VXI bus mainframe. Two of the instruments are commercially available, a power meter and a 4 - 12.4 GHz signal generator. The third instrument that provides the W-band capability was developed at the Naval Research Laboratory (NRL). This instrument incorporates functions of W-band signal and noise generation and frequency measurement down conversion. The W-band output frequency is accurate to  $\pm 10$  Hz and has 1 mW maximum power output with AM, FM and pulse modulation capability. The noise source provides an ENR > 15 dB. The measurement down converter translates the frequency to facilitate noise and spectral analysis. Software resident in the instrument controller integrates and controls the functionality of the instruments while providing a simple interface for the user.

The W-band instrument is believed to be the first VXI instrument to operate above the microwave frequency range. The microwave signal generator provides reference signals to achieve the indicated frequency accuracy of the measurement system. The power meter, with the appropriate sensor, provides the capability to measure system power. With a sensor operating in the down conversion frequency range, the power meter is also used for operations requiring noise measurements. The solid state noise source provided with the system is also unique, and a product of an NRL contract.

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**Title:** Multidimensional Electromagnetic Simulation of Microwave and Millimeter-Wave Structures

**Author(s):** J. A. Molnar and C. M. Crown

**E-mail Address:** molnar@itd.nrl.navy.mil

**Citation:** International Symposium on Recent Advances in Microwave Technology, Delhi India

**Date:** December 1993

**Report No.:** CS-93-043

**Abstract:**

We address the multidimensional determination of electromagnetic fields in structures found in microwave and millimeter wave circuits. From these fields measures of circuit behavior may be found such as s-parameters. Computational techniques appropriate for finding EM fields and their relative capabilities are examined.

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**Title:** VXI Millimeter-Wave Signal Generator Architecture

**Author(s):** J. A. Molnar

**E-mail Address:** molnar@itd.nrl.navy.mil

**Citation:** International Symposium on Recent Advances in Microwave Technology, Delhi India

**Date:** December 1993

**Report No.:** CS-93-044

**Abstract:**

The trend in instrumentation over the last several years has been toward developing measurement systems composed of instrument modules that comply with standard backplane and chassis specifications. Arising from this trend have been two competitive standard commercial implementations: VXI (VME Extensions for Instrumentation) and MMS (Modular Measurement System). For the most part, VXI instruments have been developed for digital, RF and low frequency microwaves, while MMS (spurred by the initial development of the standard by Hewlett-Packard) has focused most of the instrument development at the microwave frequency range. Compelling reasons do not limit VXI or MMS to a niche in instrumentation development.

As such, our work has centered on the development of an architecture for implementing millimeter wave signal generation in modular instruments. We have demonstrated the concept by developing a VXI signal generation module for the WR-10 frequency band (75 - 110 GHz). The WR-10 VXI signal generator provides a highly accurate frequency output with moderate power (> 0 dBm) across the band, the capability to provide a fixed attenuation or fixed output power level, and built-in modulation.

We describe our architecture and discuss its value in extending VXI signal generation instrumentation from the microwave region (EIP provides a commercial VXI signal generator for the 4 - 12.4 GHz band) through the millimeter wave region. As an example of an implementation of the architecture we present our efforts at WR-10 band. Within the discussion of the WR-10 VXI signal generator, we present the results of a unique implementation of direct digital synthesis to provide internal modulation capabilities for the instrument.

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**Title:** Integration of TAE Plus with Empress Database Management Software

**Author(s):** C. Barclay and J. A. Molnar

**E-mail Address:** molnar@itd.nrl.navy.mil

**Citation:** Tenth TAE User's Conference, Goddard Space Flight Center, Greenbelt, MD

**Date:** June 1993

**Report No.:** CS-93-045

**Abstract:**

The Fault Isolation System (FIS) is an expert system shell, developed at NRL, to provide model based diagnosis of electronic systems. An electronic system model contains information relating component interconnection, test points, tolerances and instructional information. The model information must be formatted and compiled before yielding a functional expert system. The first method developed to perform FIS knowledge acquisition was the FIS editor, which while functional and accurate in formatting, did not deliver the desired quality of ease of use; consequently it was difficult to learn and use. Furthermore, it was impossible to perform routine database functions such as sorting and searching.

Another program was needed to facilitate knowledge acquisition - one which combined the features of database management and a robust graphical user interface. No one application fulfilled both requirements. We addressed this deficiency with a plan to integrate available database functionality with format requirements imposed by FIS and improve the user interface through intuitive graphical features. Empress was chosen as a suitable database environment and TAE was selected to facilitate development of the user interface. Both programs provided C libraries with tools to help write programs. The result of the integrated effort is FISDMPro, the Fault Isolation System Database Manager.

FISDMPro contains two functional areas: conversion of data between different formats, and data acquisition and manipulation. FISDMPro provides conversion between data types to accommodate data prepared with other software tools. Special purpose code was developed primarily for the conversion procedures; interactions with TAE and Empress are superficial. Windows created with TAE provide directed access to the Unix file system. Empress commands are used only to access database entry fields. The utilization of TAE and Empress functionality is mostly required for data acquisition and manipulation. Using TAE commands, menu windows were built to guide the user through a sequence of options. Data was able to be sorted and displayed in a manner much easier to read than previous Unix command oriented versions. Windows with scroll bars assist the user in viewing the data. When the user is viewing data records, the ability to modify the record is simplified to pointing at the data field desired and clicking. A cursor prompts for new data.

TAE, using the X-Windows GUI, combined with Empress, provides an impressive array of functions for data manipulation and display. By providing a standard interface, the look and feel of the application is preserved among functions. By using X-Windows, the program is platform independent. Integration of the two programs provides a powerful set of commands with which to develop software.

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**1993 TECHNICAL REPORT ORDER FORM**  
**Communication Systems, Code 5520**

- [ ] **CS-93-001** A High Fidelity Network Simulator for SDI, *E. L. Althouse, D. N. McGregor, R. R. Nair, and S. G. Batsell*
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- [ ] **CS-93-044** VXI Millimeter-Wave Signal Generator Architecture, *J. A. Molnar*
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**1992 TECHNICAL REPORT ORDER FORM**  
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- [ ] **5521-92-020** Fixed- and Movable-Boundary Channel-Access Schemes for Integrated Voice/Data Wireless Networks, *J. E. Wieselthier and A. Ephremides*
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#### **IV. HUMAN-COMPUTER INTERACTION CODE 5530**

NRL's Human-Computer Interaction Lab performs interdisciplinary research on communication between people and computer systems. Human-Computer Interaction (HCI) can be viewed as the bi-directional communication of information between two powerful information processors: people and computers. Information can be in the form of data, symbolic knowledge, or control specifics. The goal of HCI research is to define the methods and management of this communication so that it is maximally effective in multiple contexts; a basic premise of work within the Lab is Human-In-the-Loop systems rather than autonomous ones. NRL's HCI Lab focuses on research leading to the development of software principles and methods to achieve this goal.

The HCI Laboratory is organized around four research areas which jointly contribute to the development of software principles and methods. These areas are voice systems, experimental testing, advanced interfaces, interface design and integration.

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**Title:** Projected Government Needs in Human Language Technology and the Role of Researchers in Meeting Them  
**Author(s):** Helen M. Gigley  
**E-mail Address:** gigley@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** March 21-24, 1993  
**Report No.:** HCI-93-001

**Abstract**

After a brief discussion of current government uses and needs for human language technology, this paper will discuss the uses which will probably survive in the future as well as attempt to define some anticipated ones. Business uses, military uses, and education/training receive the most focus today. Current state of the art technologies are providing initial resources to enable better management of the above. Suggested critical efforts to make the technologies more appropriate for the tasks at hand in the government will be discussed. A tentative view of the role of researchers, in providing the basis to obtain adequate critical natural language technologies, will be presented.

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**Title:** A User Task Analysis for Command and Control Systems and its Use in Human Computer Interaction Research  
**Author(s):** Deborah Hix  
**E-mail Address:** hix@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report NRL/MR/5530-93-7397  
**Date:** June 30, 1993  
**Report No.:** HCI-93-002

**Abstract**

The Advanced Interfaces Section of the Human-Computer Interaction (HCI) Laboratory at the Naval Research Laboratory (NRL) is engaged in creating and evaluating interactive computer systems that address the unique issues encountered in developing innovative, high performance human-computer interfaces. A goal of this project is to build a testbed based on Naval command and control (C2) systems as a vehicle for this research. Previous work at the HCI Lab has developed new interaction techniques - ways of using physical input and output devices to perform tasks in a human-computer interface. We now wish to transition into more realistic Naval-related applications for new techniques, in particular, command and control systems.

This report discusses a user task analysis performed for interactive computer-based C2 systems; this task analysis is a basis for developing and evaluating new interaction techniques. As a result of this task analysis, appropriate user tasks for incorporation into the command-and-control-like testbed will be identified. The testbed will also incorporate some of the new interaction techniques, and will be used for empirical evaluation of these techniques in human-computer interfaces.

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**Title:** Speech Evaluation in a Meteor Burst Environment  
**Author(s):** David A. Heide, George S. Kang, George Thomas, Bob Desourdis, and Ronald M. Bauman  
**E-mail Address:** heide@itd.nrl.navy.mil, kang@itd.nrl.navy.mil or thomas@itd.nrl.navy.mil  
**Citation:** 7th International Ionospheric Effect Symposium  
**Date:** May 5, 1993  
**Report No.:** HCI-93-003

**Abstract**

The Advanced Research Projects Agency (ARPA) has initiated a program to evaluate and improve the performance of meteor burst communication. The first major effort of this program was the establishment of a high-ERP MB link experiment (HEMBLE) to empirically evaluate the effectiveness of advanced antenna and modem techniques for meteor burst communication (MBC). A second goal of HEMBLE is to demonstrate its ability to satisfy those users who have a voice communication requirement. HEMBLE is able to demonstrate this for a number of reasons. The high power which is generated by the system allows it to use more of the available trails, and advanced modem techniques allow for burst transmission up to 512 kilobits per second (Kbps). In addition, advanced voice processing algorithms and hardware being developed at the Naval Research Laboratory allows speech to be compressed to 600 bps to reduce latency. A goal of this experiment will be to demonstrate half duplex, push-to-talk, interactive voice communication over the link. The first portion of this paper will describe the NRL voice processing architecture, and how this equipment is interfaced to the HEMBLE modems and message processors in order to reduce overall system latency.

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**Title:** Template Based Low Data Rate Speech Encoder  
**Author(s):** Larry Fransen  
**E-mail Address:** fransen@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report NRL/MR/5530-93-7371  
**Date:** September 30, 1993  
**Report No.:** HCI-93-004

**Abstract**

The 2400-b/s linear predictive coder (LPC) is currently being widely deployed to support tactical voice communication over narrowband channels. However, there is a need for lower-data-rate voice encoders for special applications: improved performance in high bit-error conditions, low-probability-of-intercept (LPI) voice communication, and narrowband integrated voice/data systems.

An 800-b/s voice encoding algorithm is presented which is an extension of the 2400-b/s LPC. To construct template tables, speech samples of 420 speakers uttering 8 sentences each were excerpted from the Texas Instrument - Massachusetts Institute of Technology (TIMIT) Acoustic-Phonetic Speech Data Base. Speech intelligibility of the 800-b/s voice encoding algorithm measured by the diagnostic rhyme test (DRT) is 91.5 for three male speakers. This score compares favorably with the 2400-b/s LPC of a few years ago.

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**Title:** Voice Message Systems for Tactical Applications (Canned Speech Approach)  
**Author(s):** G.S. Kang, T.M. Moran, and D.A. Heide  
**E-mail Address:** kang@itd.nrl.navy.mil, moran@itd.nrl.navy.mil, or  
heide@itd.nrl.navy.mil  
**Citation:** NRL Report NRL/FR/5530-93-9569  
**Date:** May 13, 1993  
**Report No.:** HCI-93-005

**Abstract**

One-way noninteractive voice messages are often used in tactical environments. Examples are surveillance and reconnaissance reports, tactical coordination messages, warnings, and reminders. These messages can be transmitted efficiently in terms of words, phrases, or sentences. We use a speech recognizer to convert speech into text. The resultant data rate is below 100 b/s.

At the receiver, speech is regenerated by concatenating the stored speech waveforms (canned speech) corresponding to the received indices. Intelligibility of the resultant speech is high because output speech stems from actual stored speech rather than synthetic speech. If tactical messages are generated by concatenating only words, however, we need to incorporate the sentence-level prosody in the generated speech. For tactical messages, however, prosodic rules are relatively simple because tactical messages are customarily spoken without significant pitch and rhythmic inflections. If tactical messages are generated by concatenating phrases and sentences, resultant speech will sound natural without further speech modification. Another advantage of the "canned speech" approach is that the spoken language can be translated into any one of the preselected languages at the receiver. The voice message system will play a significant role in future DoD secure voice terminals.

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**Title:** Brevity Code Usage in Aegis Team Training Communication  
**Author(s):** L.B. Achille, K.G. Schulze, and A. Schmidt-Nielsen  
**E-mail Address:** achille@itd.nrl.navy.mil, schulze@itd.nrl.navy.mil, or  
schmidt@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** May 19, 1993  
**Report No.:** HCI-93-006

**Abstract**

We recorded the internal communications during AEGIS team training and developed a classification scheme to categorize communications at the speech turn level. Subjective performance assessments made during debrief sessions did not reflect measured performance. We coded and analyzed communications emphasizing speech turns that include brevity codes. Brevity code speech turns were wordier, involved more interpreted information, and included more format violations than non-brevity code speech turns. Brevity codes were used as officially defined 54% of the time, but usage was consistent across scenarios and over training. Officers at the mid-level of the hierarchy used 60% of all brevity codes. Our results have implications for planning training strategies and evaluation methods, including performance feedback and specialized brevity code training tailored to the needs of individual team members.

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**Title:** Brevity Code Frequencies In AEGIS Team Training Communications  
(CLASSIFIED)

**Author(s):** Kay G. Schulze, Lisa B. Achille, Astrid Schmidt-Nielsen and Susan L. Feldman

**E-mail Address:** schulze@itd.nrl.navy.mil, achille@itd.nrl.navy.mil, schmidt@itd.nrl.navy.mil or feldman@itd.nrl.navy.mil

**Citation:** NRL Formal Report NRL/FR/5530-93-9574

**Date:** May 19, 1993

**Report No:** HCI-93-007

#### **Abstract**

Communications are a crucial aspect of military decision making and the use of NATO restricted brevity codes is abundant in verbal communications of AEGIS team members during training sessions and in the fleet. An understanding of the relationship between brevity code use and communication performance during AEGIS team training is important for brevity code training issues. We recorded the internal Combat Information Center (CIC) communications during AEGIS team training exercises and performed an analysis on speech turns containing brevity codes.

Brevity codes were identified, categorized, and analyzed and on average, 58% of the brevity codes used were used as defined. The remaining were used consistently as ordinary English or in a manner we designated as "Professional." Brevity codes were categorized as Professional if they were used in a consistent manner by team members in what appeared to be a mutually accepted and consistent meaning different from either the NATO or English meanings.

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**Title:** Acquiring Computer Skills: Individual Differences in Style and Ability

**Author(s):** Astrid Schmidt-Nielsen

**E-mail Address:** schmidt@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** October 11-15, 1993

**Report No.:** HCI-93-008

#### **Abstract**

A command language like UNIX is fast and powerful but requires intense learning for mastery. Mouse menus are more intuitive and require little or no memory, but they are inefficient. Keyboard shortcuts, once learned, provide a way of counteracting this. Ackerman and Woltz (1993) have found strategy differences in a consistently mapped noun pairs task. Some individuals spontaneously adopted a memory strategy while others continued to use a lookup strategy even after 1350 trials. We believe that there is a parallel between this task and the way people learn to use menus and "hot keys" in computer applications. We used learning of a graphing program to evaluate strategy differences. Despite instructions to learn as many keyboard shortcuts as possible, there were large individual differences in the number of keyboard versus mouse actions. Performance and strategy on the graphing task were related to performance on the noun pairs task and to reasoning ability.

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**Title:** Performance Issues and Analysis of Brevity Code Usage in AEGIS Communications  
**Author(s):** Kay G. Schulze, Lisa B. Achille, Astrid Schmidt-Nielsen and Susan Feldman  
**E-mail Address:** schulze@itd.nrl.navy.mil, achille@itd.nrl.navy.mil, or schmidt@itd.nrl.navy.mil  
**Citation:** NRL Formal Report NRL/FR/5522--93-9573  
**Date:** December 13, 1993  
**Report No.:** HCI-93-009

**Abstract**

Communications are a crucial aspect of military decision making. In the AEGIS Combat Information Center (CIC) context, verbal communications and the use of computerized combat systems and computerized displays interact to produce effective team performance. We recorded the internal CIC communications during AEGIS team training exercises and developed a classification scheme to categorize each communication. The team communications were coded and analyzed at the speech turn level with emphasis on the distinctions between speech turns that included the use of brevity codes and those that did not. Changes in communication patterns for a single team from early to late training were used to evaluate hypotheses about effective communication.

Changes observed with increased training include significantly more brevity code words used and significantly more format violations in brevity code speech turns than expected. The use of interpreted information significantly increased with training and was significantly more frequent in brevity code speech turns than in the transcript in general. The repetitions and error categories show no consistent trends.

The Tactical Action Officer carries the heaviest communication workload and receives the most interpreted information while producing very few of the interpreted information speech turns. By comparing speaker and receiver workload, and information distribution hierarchy for AEGIS teams is described and interpreted in the context of cognitive task analysis.

Our results have implications for planning training strategies and evaluation methods, including performance feedback and specialized training tailored to the needs of individual team members.

---

**Title:** Focus in Graphical User Interfaces  
**Author(s):** Manuel A. Perez and John L. Sibert  
**E-mail Address:** perez@itd.nrl.navy.mil or sibert@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** January 4-7, 1993  
**Report No.:** HCI-93-010

**Abstract**

Focus in natural language processing is used to keep track of the attentional space of the participants in the dialogue. Graphical interfaces have still to benefit from the use of this level of communication. We discuss a graphical interface counter part called a focus space. Focus spaces can be used to combine multiple interaction styles (e.g. natural language with graphical pointing). We describe how a specific theory of discourse structure and focus space can be applied to graphical interfaces. The attentional space is maintained automatically by the system, and can be used by the software under program control. An example is provided showing how the attentional space can be used.

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**Title:** What You Look at is What You Get: Eye Movement User Interfaces  
**Author(s):** Robert J.K. Jacob  
**E-mail Address:** jacob@itd.nrl.navy.mil  
**Citation:** "Hot Topics" column, IEEE Computer  
**Date:** July 1, 1993  
**Report No.:** HCI-93-011

**Abstract**

As computers become more powerful, the critical bottleneck in their use is often in the interface to the user rather than the computer processing itself. A goal of research in human-computer interaction is to increase the communication bandwidth between the user and the machine.

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**Title:** The Egocentric Projection of Imagery in Front of the Screen (Back Through the Looking Glass)  
**Author(s):** James N. Templeman  
**E-mail Address:** templeman@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** April 15, 1993  
**Report No.:** HCI-93-012

**Abstract**

We call the interactive viewing technique in which the head is tracked and the scene is projected to the user's physical viewpoint egocentric projection. This paper points out properties associated with the egocentric projection of imagery in front of the screen, and suggests how they can be applied.

A virtual object must be in front of the screen for its projected screen image to expand as a user moves toward it. When the entire scene consists of a single flat picture in front of the screen, head movements provide a natural, hands-free way to pan-and-zoom over it. The reactive display exhibits optical flow, a natural form of dynamic feedback that guides the user in selecting a view. This gives the user access to a virtual viewing surface much larger than the display screen. Three dimensional features may be added to strengthen the effect.

In terms of Gibson's (1986) ecological approach to visual perception, this technique seeks to carry many of the variant and invariant properties of the natural visual environment to interactive computer graphic displays.

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**Title:** Pre-screen Projection of Virtual Scenes  
**Author(s):** James N. Templeman  
**E-mail Address:** templeman@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** October 18, 1993  
**Report No.:** HCI-93-013

**Abstract**

The natural way a person controls their view can be mimicked by tracking their head and projecting the scene to their physical viewpoint. Only when a virtual object falls in front of the screen will its image expand as the user moves toward it. This paper explains the use of pre-screen projection to extend the virtual viewing surface, magnify 3D objects, and pan-and zoom over maps.

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**Title:** Extending Virtual Reality Out in Front of the Screen  
**Author(s):** James N. Templeman  
**E-mail Address:** templeman@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** June 22, 1993  
**Report No.:** HCI-93-014

**Abstract**

Our view of the world changes whenever we move our head. We are familiar with the way our view changes as we move about. We control our view by positioning our head. By tracking a person's head and making the viewpoint used to compute a projected scene correspond to our physical viewpoint, head motion can be used to control the view of synthetic imagery.

This technique has been used to construct virtual realities visible within the confines of a stationary screen. It is referred to as "non-immersive", "desktop", or "fish-tank" VR. Most work has been done with scenes falling near or behind the surface of the screen to make the illusion of 3D as realistic as possible. Stereo display further enhances the effect (Deering 1992; Paley 1993; Ware, Arthur, and Booth 1993).

An alternate approach is presented here. The scene is portrayed as if it existed in front of the screen to amplify the control exerted by our head movements, as in Figure 1. This approach emphasizes using the head to control the view in a natural way, instead of striving for 3D realism. It provides a natural, hands free method of panning and zooming over a virtual landscape.

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**Title:** Delivery of Information Through Sound  
**Author(s):** James A. Ballas  
**E-mail Address:** ballas@itd.nrl.navy.mil  
**Citation:** Santa Fe Institute Studies in Sciences of Complexity, Addison-Wesley  
**Date:** January 1, 1993  
**Report No.:** HCI-93-015

**Abstract**

The potential to deliver information through sound is rapidly expanding with new technology, new techniques, and significant advances in our understanding of hearing. Although these changes raise important new issues about the design of sound delivery systems, there is already a wide range of knowledge about sound display that can be helpful, scattered through different disciplines. An overview of how sound can deliver information will be presented using a framework of linguistic analogies. Areas that will be discussed in some detail include contextual and expectancy effects, which operate not only when tonal sounds, but also when realistic sounds are interpreted.

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**Title:** Including the Human Element in Design of Command and Control Decision Support Systems: The KOALAS Concept  
**Author(s):** CDR Rodney A. Colton and CDR Robert H. Ganze  
**E-mail Address:** library@aic.nrl.navy.mil  
**Citation:** NRL Memorandum Report NRL/MR/5534--93-7309  
**Date:** March 26, 1993  
**Report No.:** HCI-93-016

**Abstract**

The rapidly developing technology of command and control and decision support systems requires improvement in the way the human element is integrated into the system. The limitations of human cognitive capacity must not be exceeded, or the system will fail.

A properly designed decision support system should include provision for the heuristics that are likely to be employed by a decision maker when faced with a rapidly changing and information intensive situation and incomplete or questionable data.

Many measures of effectiveness have been proposed for battle management and C<sup>2</sup> systems. In this paper, where systems consist of an integrated combination of a human decision maker and his decision support system, three measures of effectiveness are proposed and discussed. Improvements in performance of the total system can be made by improving the efficiency of information exchange between the DM and the support system.

The KOALAS architecture has been shown to be an effective implementation of a simulation and rule based expert system which can increase the efficiency of information exchange between the human decision maker and the decision support system. Potential improvements in KOALAS' Architecture are discussed with recommendations for improving its employment and utility.

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**Title:** Common Factors in the Identification of an Assortment of Brief Everyday Sounds

**Author(s):** James A. Ballas

**E-mail Address:** ballas@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** April 1993

**Report No.:** HCI-93-017

#### **Abstract**

Acoustic, ecological, perceptual and cognitive factors that are common in the identification of 41 brief, varied sounds were evaluated. In Experiment 1, identification time and accuracy, causal uncertainty values, and spectral and temporal properties of the sounds were obtained. Experiment 3 solicited perceptual-cognitive ratings. Factor analyses of spectral parameters and perceptual-cognitive ratings were performed. Identification time and causal uncertainty are highly interrelated, and both are related to ecological frequency and the presence of harmonics and similar spectral bursts. Experiments 4 and 5 used a priming paradigm to verify relationships that correlate between identification time and causal uncertainty and to assess the effect of sound typicality. Results support a hybrid approach for theories of everyday sound identification.

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**Title:** Software Review

**Author(s):** James A. Ballas

**E-mail Address:** ballas@itd.nrl.navy.mil

**Citation:** Internal Report

**Date:** August 18, 1993

**Report No.:** HCI-93-018

#### **Abstract**

This software package (Version 2.1 was evaluated) provides image decompression, display, editing, printing, and conversion capability for PC systems using Windows. The key advertised capability is that image decompression uses a fractal model of the image. The details of fractal image compression will not be covered in this review. Interested readers can find this information in Fractal Image Compression by Barnsley.

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**Title:** The Damage Control Information Display System for the Ex-USS Shadwell  
**Author(s):** David L. Tate  
**E-mail Address:** tate@itd.nrl.navy.mil  
**Citation:** NRL Report NRL/FR/5535--93-9589  
**Date:** September 30, 1993  
**Report No.:** HCI-93-019

**Abstract**

The Damage Control Information Display System (DCIDS) is a graphical information-retrieval and equipment-control system that gives shipboard damage control personnel the ability to detect, analyze, and combat various types of damage control situations. A prototype of DCIDS has been developed for use aboard the ex-USS Shadwell, the Navy's full scale fire research and test ship from which damage control and ship survivability investigations, analyses, and evaluations are performed. This DCIDS implementation runs on a PC-compatible computer under MicroSoft Windows and communicates with the Shadwell's data collection computer through an Ethernet TCP/IP connection. This report describes the operation and use of the DCIDS program, and provides the user interface and information management specifications for modification of the program for other fire test scenarios and equipment interfacing.

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**Title:** New Human-Computer Interaction Techniques  
**Author(s):** Robert J.K. Jacob  
**E-mail Address:** jacob@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** September 14, 1993  
**Report No.:** HCI-93-020

**Abstract**

This chapter describes the area of human-computer interaction techniques in general and then describes research in several new types of interaction techniques under way at the Human-Computer Interaction Laboratory of the U.S. Naval Research Laboratory; eye movement-based interaction techniques, three-dimensional pointing, and, finally, using dialogue properties in interaction techniques.

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**Title:** Interaction Styles and Input/Output Devices  
**Author(s):** R.J.K. Jacob, J. Leggett, B. Meyers and R. Pausch  
**E-mail Address:** jacob@itd.nrl.navy.mil, leggett@cs.tamv.edu, bam@a.gp.cs.cmu.edu or pausch@cs.virginia.edu  
**Citation:** Behaviour & Information Technology, v12, n2, 69-79  
**Date:** May 1, 1993  
**Report No.:** HCI-93-021

**Abstract**

The bottleneck in improving the usefulness of interactive systems increasingly lies not in performing the processing task itself but in communicating requests and results between the system and its user. The best leverage for progress in this area therefore now lies at the user interface, rather than the system internals. Faster, more natural, and more convenient means for users and computers to exchange information are needed. On the user's side, interactive system technology is constrained by the nature of human communication organs and abilities; on the computer side, it is constrained only by input/output devices and methods that we can invent. The challenge before us is to design new devices and types of dialogues that better fit and exploit the communication-relevant characteristics of humans.

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**Title:** A UIMS Architecture for Focus Processing in a Graphical User Interface  
**Author(s):** Manuel A. Perez and Robert J.K. Jacob  
**E-mail Address:** perez@itd.nrl.navy.mil or jacob@itd.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** December 1, 1993  
**Report No.:** HCI-93-022

**Abstract**

Today's graphical user interface remembers little from one transaction to the next; each command exists nearly independently. Humans, however, typically draw on previous elements of a dialogue in their communications. We are seeking to add some of the characteristics of human dialogues to graphical interfaces. This paper describes our research into this problem and our initial results in answering three questions: What are the appropriate analogues of conversational focus in a graphical human-computer conversation? Where does this type of processing best fit within a user interface management system paradigm? What mechanisms can be used to realize it?

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**1993 TECHNICAL REPORT ORDER FORM**  
**Human-Computer Interaction, Code 5530**

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- [ ] **HCI-93-002** A User Task Analysis for Command and Control Systems and its Use in Human Computer Interaction Research, *Deborah Hix*
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- [ ] **HCI-93-015** Delivery of Information Through Sound, *James A. Ballas*
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- [ ] **HCI-93-020** New Human-Computer Interaction Techniques, *Robert J.K. Jacob*
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- [ ] **HCI-93-022** A UIMS Architecture for Focus Processing in a Graphical User Interface, *Manuel A. Perez and Robert J.K. Jacob*



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**Human-Computer Interaction, Code 5530**

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- [ ] **HCI-92-037** Intelligibility and Acceptability Testing for Speech Technology, *A. Schmidt-Nielsen*
- [ ] **HCI-92-038** Direct Manipulation and Intermittent Automation in Advanced Cockpits, *J. Ballas, C. L. Heitmeyer, and M. A. Perez*
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- [ ] **HCI-92-040** Human-Computer Interaction in Encyclopedia of Artificial Intelligence, *R.J.K. Jacob*
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- [ ] **HCI-92-042** Engineering Case Tools to Support Formal Methods for Real-Time Software Development, *C. L. Heitmeyer, P. C. Clements, B. G. Labaw, and A. Mok*
- [ ] **HCI-92-043** Interpreting the Language of Informational Sound, *J. Ballas*
- [ ] **HCI-92-044** The Perceptual Structure of Multidimensional Input Device Selection, *R.J.K. Jacob and L. E. Sibert*
- [ ] **HCI-92-045** Evaluating Two Aspects of Direct Manipulation in Advanced Cockpits, *J. A. Ballas, C. L. Heitmeyer, and M. A. Perez*
- [ ] **HCI-92-046** Eye Movement-Based Human Computer Interaction Techniques: Toward Non-Command Interfaces, *R.J.K. Jacob*
- [ ] **HCI-92-047** Evaluation Criteria for Real-Time Specification Languages, *P.C. Clements, C.B. Gasarch, and R. Jeffords*
- [ ] **HCI-92-048** A Graphical User Interface for Shipboard Damage Control, *D. L. Tate*

**V. CENTER FOR COMPUTER HIGH ASSURANCE SYSTEMS  
CODE 5540**

The Center for Computer High Assurance Systems performs research and develops technology in areas supporting military requirements for communication security (COMSEC) and computer security (COMPUSEC). Emphasis is given to the development of concepts, architectures, analysis techniques and methodology that exploit appropriately the opportunities available through systematic consideration of the total security problem and its impact on communication and computer systems. The Center provides leadership and is the Navy's lead laboratory for research and development of COMPUSEC technology and evaluation techniques. Areas of activity include development of information security devices, subsystems and system technology through the conceptual, analysis and experimentation, and proof-of-concept phases. The Center works closely with Navy system developers and with the National Security Agency.

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**Title:** A Practical Transaction Model and Untrusted Transaction Manager for a Multilevel-Secure Database System

**Author(s):** Myong H. Kang, Oliver Costich and Judith N. Froscher

**E-mail Address:** mkang@itd.nrl.navy.mil

**Citation:** Book Chapter, Database Security VI: Status and Prospects, Bhavani Thuraisingham and Carl E. Landwehr (editors), North-Holland, 285-300

**Date:** 1993

**Report No.:** CCHAS-93-001

**Abstract:**

A new transaction model for multilevel-secure databases which use the replicated architecture is presented. A basic concurrency control algorithm and two variations are given based on this transaction model. We also present new correctness criteria for multilevel-secure databases which use the replicated architecture. Based on this criteria, we prove that our algorithms are correct.

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**Title:** Orange Locking: Channel-Free Database Concurrency Control via Locking

**Author(s):** John P. McDermott and Sushil Jajodia

**E-mail Address:** mcdermott@itd.nrl.navy.mil

**Citation:** Book Chapter, Database Security VI: Status and Prospects, Bhavani Thuraisingham and Carl E. Landwehr (editors), North-Holland, 267-284

**Date:** 1993

**Report No.:** CCHAS-93-002

**Abstract:**

The concurrency control lock (e.g. file lock, table lock) has long been used as a canonical example of a covert channel in a database system. Locking is a fundamental concurrency control technique used in many kinds of computer systems beside database systems. Locking is generally considered to be interfering and hence unsuitable for multilevel systems. In this paper we show how such locks can be used for concurrency control, without introducing covert channels.

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**Title:** A Logical Language for Specifying Cryptographic Protocol Requirements

**Author(s):** Paul F. Syverson

**E-mail Address:** syverson@itd.nrl.navy.mil

**Citation:** Proceedings of the 1993 IEEE Symposium on Research on Security and Privacy, IEEE Press, 165-177

**Date:** April 1993

**Report No.:** CCHAS-93-003

**Abstract:**

In this paper we present a formal language for specifying and reasoning about cryptographic protocol requirements. We give examples of simple sets of requirements in that language. We look at two versions of a protocol that might meet those requirements and show how to specify them in the language of the NRL Protocol Analyzer. (cf. [Mea91], [Mea92]) We also show how to map one of our sets of formal requirements to the language of the NRL Protocol Analyzer and use the Analyzer to show that one version of the protocol meets those requirements. In other words, we use the Analyzer as a model checker to assess the validity of the formulae that make up the requirements.

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**Title:** On Introducing Noise into the Bus-Contention Channel  
**Author(s):** James W. Gray, III  
**E-mail Address:** gray@cs.ust.hk  
**Citation:** Proceedings of the IEEE Computer Society Symposium on Research in Security and Privacy, 90-98, IEEE Press  
**Date:** May 1993  
**Report No.:** CCHAS-93-004

**Abstract:**

We explore two approaches to introducing noise into the bus-contention channel: an existing approach called fuzzy time, and a novel approach called probabilistic partitioning. We compare the two approaches in terms of the impact on covert channel capacity, the impact on performance, the amount of random data needed, and their suitability for various applications. For probabilistic partitioning, we obtain a precise tradeoff between covert channel capacity and performance.

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**Title:** On Analyzing the Bus-Contention Channel Under Fuzzy Time  
**Author(s):** James W. Gray, III  
**E-mail Address:** gray@cs.ust.hk  
**Citation:** Computer Security Foundations Workshop VI Proceedings, 3-9, IEEE Press  
**Date:** June 15-17, 1993  
**Report No.:** CCHAS-93-005

**Abstract:**

We argue that Hu's analysis of the capacity of the bus-contention channel under fuzzy time makes an assumption about the environment that is too strong for many practical purposes. We show how to analyze the capacity of the channel under a weaker, and more appropriate assumption. We compute the capacity of the channel using realistic system parameters and the value we obtain indicates that under the weaker assumption, fuzzy time is much less effective than what is claimed by Hu.

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**Title:** Comparing Different Approaches for Specifying and Verifying Real-Time Systems  
**Author(s):** C. Heitmeyer, R. Jeffords and B. Labaw  
**E-mail Address:** heitmeyer@itd.nrl.navy.mil  
**Citation:** Proceedings of the Tenth IEEE Workshop on Real-Time Operating Systems and Software, IEEE Press, New York, NY  
**Date:** May 13-14, 1993  
**Report No.:** CCHAS-93-006

**Abstract:**

The paper presents a benchmark for comparing different real-time formalisms, describes three classes of formalisms that can be applied, and summarizes efforts currently in progress to specify the system described by the benchmark and prove properties about its behavior.

---

**Title:** Toward a Comprehensive INFOSEC Certification Methodology  
**Author(s):** Charles N. Payne, Jr., Judith N. Froscher and Carl E. Landwehr  
**E-mail Address:** payne@itd.nrl.navy.mil  
**Citation:** Proceedings Sixteenth National Computer Security Conference,  
Baltimore, MD, NIST/NSA, 165-172  
**Date:** September 1993  
**Report No.:** CCHAS-93-007

**Abstract:**

Accreditors want to know what vulnerabilities will exist if they decide to turn on a system. TCSEC evaluations address products, not systems. Not only the hardware and software of a system are of concern; the accreditor needs to view the system components in relation to the environment in which they operate and in relation to the system's mission. This paper proposes an informal but comprehensive approach that can provide the accreditor with the necessary information. First, we discuss the identification of assumptions and assertions that reflect INFOSEC requirements. Second, we propose the definition of an assurance strategy to integrate security engineering and system engineering. The assurance strategy initially documents the set of assumptions and assertions derived from the requirements. It is elaborated and refined throughout the development, yielding the assurance argument, delivered with the system, which provides the primary technical basis for the certification decision. With the assurance strategy in place, certification of the trusted system can become an audit of the development process.

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**Title:** Panel on Cryptographic Protocol Models and Requirements  
**Author(s):** Paul F. Syverson  
**E-mail Address:** syverson@itd.nrl.navy.mil  
**Citation:** Proceedings of the IEEE Computer Security Foundations Workshop VI,  
IEEE Press, 161  
**Date:** June 1993  
**Report No.:** CCHAS-93-008

**Abstract:**

Most research in the analysis of cryptographic protocols to date has focused on the development and implementation of formal methods for specification and verification. This panel discusses two largely overlooked areas: requirements for cryptographic protocols and the development of appropriate models of computation. The goal here is to explore whether or not the focus of research should be shifted more in these directions.

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**Title:** Consistency Checks for SCR-Style Requirements Specifications  
**Author(s):** C. Heitmeyer and B. Labaw  
**E-mail Address:** heitmeyer@itd.nrl.navy.mil  
**Citation:** NRL Report, NRL/FR/5540--93-9586  
**Date:** December 31, 1993  
**Report No.:** CCHAS-93-009

**Abstract:**

This report describes a class of software tools that check formal requirements specifications for consistency with a requirements model. The model, which describes properties of requirements specifications based on the SCR (Software Cost Reduction) approach to requirements, is summarized. Two experiments are described in which condition tables and mode transition tables in an updated version of the A-7 requirements document were checked for selected properties using tools we developed. The significant number of errors found by the tools is summarized. Tool-based techniques and manual

techniques for performing consistency checks are compared, and several additional consistency checks, derived from the formal model, are identified. Conclusions are presented concerning the utility, cost, and scalability of tool-based consistency checking.

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**Title:** Panel Descriptions: Computer Security Tradeoffs

**Author(s):** Catherine Meadows

**E-mail Address:** meadows@itd.nrl.navy.mil

**Citation:** Proceedings of the 1993 Complex Systems Engineering Synthesis and Assessment Technology Workshop (CSESATW 93), NSWC, 373-374

**Date:** July 20-21, 1993

**Report No.:** CCHAS-93-010

**Abstract:**

In order to build a secure system in which various critical properties can be guaranteed to an acceptable degree, it is necessary to understand the tradeoffs between security and the other properties. In this paper we give a list of questions that need to be discussed before we can achieve such an understanding.

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**Title:** Models of Confidentiality: Past, Present, and Future

**Author(s):** John D. McLean

**E-mail Address:** mclean@itd.nrl.navy.mil

**Citation:** Proceedings of the IEEE Computer Security Foundations Workshop VI, IEEE Press, 86-90

**Date:** June 1993

**Report No.:** CCHAS-93-011

**Abstract:**

This paper presents my answers to four questions we were asked to address during this panel: (1) What did I think were the foundations of computer security in 1988 (the date of the first IEEE Workshop on the Foundations of Computer Security), (2) Have any of those foundations been laid, (3) What do I currently think are the foundations of computer security, and (4) Where do I think we should be devoting our efforts in the future.

---

**Title:** Performance Analysis of Transaction Management Algorithms for the SINTRA Replicated-Architecture Database System

**Author(s):** John P. McDermott and Ravi Mukkamala

**E-mail Address:** mcdermott@itd.nrl.navy.mil

**Citation:** Proceedings Seventh Annual IFIP WG11.3 Working Conference on Database Security, Huntsville, AL, 216-240

**Date:** September 1993

**Report No.:** CCHAS-93-012

**Abstract:**

The most critical problem associated with implementing replicated architecture multilevel-secure database systems is transaction management: concurrency control, mutual consistency of replicas, and atomic recovery from failures, under the constraints of multilevel security. This paper investigates and compares the performance of five of the most promising transaction management approaches, via analytic performance modeling. We find that all five have acceptable performance and, over a wide range of circumstances, can be chosen based on structural considerations rather than performance.

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**Title:** An International Survey of Industrial Application of Formal Methods: Purpose, Approach, Analysis, and Conclusions

**Author(s):** D. Craigen, S. Gerhart and T. Ralston

**E-mail Address:** heitmeyer@itd.nrl.navy.mil

**Citation:** NRL Report, Volume I, NRL/FR/5546--93-9581

**Date:** September 30, 1993

**Report No:** CCHAS-93-013

**Abstract:**

Formal methods are mathematically-based techniques, often supported by reasoning tools that can offer a rigorous and effective way to model, design, and analyze computer systems. The purpose of this study is to evaluate international industrial experience in using formal methods. The cases selected are, we believe, representative of industrial-grade projects and span a variety of application domains. The study had three main objectives:

- to better inform deliberations within industry and government on standards and regulations;
- to provide an authoritative record on the practical experience of formal methods to date; and
- to suggest areas where future research and technology developments are needed.

This first volume describes the study, the formal methods, the cases that were studied, our approach to performing the study, and our analysis, findings, and conclusions.

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**Title:** An International Survey of Industrial Application of Formal Methods: Case Studies

**Author(s):** D. Craigen, S. Gerhart and T. Ralston

**E-mail Address:** heitmeyer@itd.nrl.navy.mil

**Citation:** NRL Report, Volume II, NRL/FR/5546--93-9582

**Date:** September 30, 1993

**Report No:** CCHAS-93-014

**Abstract:**

This second volume provides the details on the case studies.

---

**Title:** Maintaining Multilevel Transaction Atomicity in MLS Database Systems with Kernelized Architecture

**Author(s):** Oliver Costich and Sushil Jajodia

**E-mail Address:** costich@itd.nrl.navy.mil

**Citation:** Book Chapter, Database Security VI: Status and Prospects, Bhavani Thuraisingham and Carl E. Landwehr (editors), North-Holland, 249-266

**Date:** Spring 1993

**Report No.:** CCHAS-93-015

**Abstract:**

In most models of trusted database systems, transactions are considered to be single-level subjects. As a consequence, users are denied the ability to execute some transactions that can be run on conventional (untrusted) database systems, namely those that perform functions that become inherently multilevel in the MLS environment. This paper introduces a notion of multilevel transaction and proceeds to an algorithm for their concurrent execution. The algorithm is proven to be correct in the sense that the resulting schedule for executing the multilevel transactions is one-copy serializable.

---

**Title:** Applying Formal Methods to an Embedded Real-Time Avionics System  
**Author(s):** P. Clements, C. Heitmeyer and B. Labaw  
**E-mail Address:** heitmeyer@itd.nrl.navy.mil  
**Citation:** Proceedings First International Workshop on Real-Time Applications, New York, NY  
**Date:** May 11-12, 1993  
**Report No:** CCHAS-93-016

**Abstract:**

We present an application of a formal development methodology to an actual real-time embedded system. The formal methods used are based on Modechart, a graphical state specification language for real-time systems, whose formal semantic definition provides the basis for analysis. The specifications may be automatically simulated, or verified with respect to user-provided safety, liveness, and timing assertions. The application is of non-toy size and functionality, and features many state-of-the-practice design properties, such as parallel priority-based synchronization processes with preemption.

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**Title:** Design Documentation for the SINTRA Global Scheduler  
**Author(s):** Myong H. Kang and Rodney Peyton  
**E-mail Address:** mkang@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report, NRL/MR/5542--93-7362  
**Date:** June 30, 1993  
**Report No.:** CCHAS-93-017

**Abstract:**

This report presents the detailed description of the Secure Information Through Replicated Architecture (SINTRA) global scheduler. The detailed description includes: (1) the replica control algorithm, (2) design descriptions, and (3) rationale behind the choice of a specific methodology, implementation language, and software engineering principles.

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**Title:** MT: A Toolset for Specifying and Analyzing Real-Time Systems  
**Author(s):** P. Clements, C. Heitmeyer, B. Labaw and A. Rose  
**E-mail Address:** heitmeyer@itd.nrl.navy.mil  
**Citation:** Proceedings of the Real-Time Systems Symposium, 12-22  
**Date:** December 1-3, 1993  
**Report No:** CCHAS-93-018

**Abstract:**

This paper introduces MT, a collection of integrated tools for specifying and analyzing real-time systems using the Modechart language. The toolset includes facilities for creating and editing Modechart specifications. Users may symbolically execute the specifications with an automatic simulation tool to make sure that the specified behavior is what was intended. They may also invoke a verifier that uses model-checking to determine whether the specifications imply (satisfy) any of a broad class of safety assertions. To illustrate the toolset's capabilities as well as several issues that arise when formal methods are applied to real-world systems, the paper includes specifications and analysis procedures for a software component taken from an actual Navy real-time system.

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**Title:** Integrating Specifications, Integrating Assurances  
**Author(s):** John D. McLean  
**E-mail Address:** mclean@itd.nrl.navy.mil  
**Citation:** Proceedings of the National Computer Security Conference, 355-357  
**Date:** October 1993  
**Report No.:** CCHAS-93-019

**Abstract:**

Evaluated products come with a specification and some assurance level that reflects the accuracy of the specification. Composition of evaluated products, therefore, entails composition of specifications and of assurance levels. This paper examines both types of composition and draws some conclusions.

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**Title:** Comparing Formal Approaches for Specifying and Verifying Real-Time Systems  
**Author(s):** C. Heitmeyer, R. Jeffords and B. Labaw  
**E-mail Address:** heitmeyer@itd.nrl.navy.mil  
**Citation:** Proceedings of the Complex Systems Engineering Synthesis and Assessment Workshop (CSESAW '93), Washington, DC, 300-308  
**Date:** July 20-22, 1993  
**Report No:** CCHAS-93-020

**Abstract:**

This paper describes three formal approaches that can be applied to the specification and analysis of real-time systems, namely, process algebra, model checking, and general-purpose theorem proving; provides a formal statement of a benchmark problem for comparing different formalisms; and summarizes efforts currently in progress to use each approach to specify the system of interest and prove properties about its behavior. Three sets of initial results are described: one set based on the process algebra CSP, a second set based on the use of the theorem proving system PVS, and a third set based on using the EVES theorem-prover.

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**Title:** Dependable Computing for Critical Applications 3  
**Author(s):** Carl E. Landwehr, Brian Randall and Luca Simoncini (editors)  
**E-mail Address:** landwehr@itd.nrl.navy.mil  
**Citation:** Book, ISBN: 0-387-82481-2, Springer-Verlag, Wien-New York, 381 pages  
**Date:** September 1993  
**Report No.:** CCHAS-93-021

**Abstract:**

This volume contains the papers presented at the Third IFIP International Working Conference on Dependable Computing for Critical Applications, sponsored by IFIP WG 10.4, as revised by the authors following presentation. System developers increasingly apply computers where they can affect the safety and security of people and equipment. This conference, like its predecessors, addressed various aspects of computer system dependability, a broad term defined as the degree of trust that may justifiably be placed in a system's reliability, availability, safety, security, and performance. The program committee selected 18 papers for presentation from a total of 74 submissions. The resulting program represented a broad spectrum of interests, with papers from universities, corporations, and government agencies in eight countries.

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**Title:** Towards Real ATM Interoperability  
**Author(s):** Randall J. Atkinson  
**E-mail Address:** atkinson@itd.nrl.navy.mil  
**Citation:** CONNEXIONS The Interoperability Report, v7, n8  
**Date:** August 1993  
**Report No:** CCHAS-93-022

**Abstract:**

A synchronous Transfer Mode (ATM) networking technology and the related Synchronous Optical Network (SONET) technology are both important for future data and telecommunications networks. This article describes the emerging ATM/SONET technology for high-speed networks. ATM specification status, possible roles for ATM, ATM signaling protocol specification, and prospects for near-term multi-vendor interoperability are also discussed. Special attention is paid to the relationship between existing TCP/IP networks and the future ATM/SONET technology. Areas requiring additional research are identified.

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**Title:** On Key Distribution Protocols for Repeated Authentication  
**Author(s):** Paul F. Syverson  
**E-mail Address:** syverson@itd.nrl.navy.mil  
**Citation:** Operating Systems Review, v27, n4, 24-30  
**Date:** October 1993  
**Report No.:** CCHAS-93-023

**Abstract:**

In [KSL92], Kehne et al. presents a protocol (KSL) for key distribution. Their protocol allows for repeated authentication by means of a ticket. They also give a proof in BAN logic [BAN89] that the protocol provides the principals with a reasonable degree of trust in the authentication and key distribution. They present an optimality result that their protocol contains a minimal number of messages. Nonetheless, in [NS93] Neuman and Stubblebine present a protocol (NS) as an explicit alternative to KSL that requires one less message in the initial authentication and key distribution. One goal of this paper is to examine some of the reasons for this discrepancy. Another goal is to demonstrate possible attacks on NS. Like any attacks on cryptographic protocols, these depend on assumptions about implementation details. But, when possible they are serious: a penetrator can initiate the protocol, masquerade as another principal, obtain the session key, and even generate the session key herself. We will set out implementation assumptions required for the attacks to take place and implementation assumptions that preclude such an attack. We will also look at other protocols, including one that is not subject to this form of attack and has the same number of messages as NS. Finally, we will briefly discuss the logical analysis of these repeat authentication protocols.

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**Title:** Database Security VI: Status and Prospects  
**Author(s):** Bhavani Thuraisingham and Carl E. Landwehr (editors)  
**E-mail Address:** landwehr@itd.nrl.navy.mil  
**Citation:** Book, ISBN: 0-444-89889-1, North-Holland, New York  
**Date:** Spring 1993  
**Report No.:** CCHAS-93-024

**Abstract:**

This volume contains the papers presented at the Sixth IFIP WG11.3 Working Conference on Database Security, as revised by the authors following presentation, together with an account of the discussions held during the meeting and the IFIP WG11.3

Research Questions List. Papers presented covered a wide range of topics in database security including the semantics of multilevel database applications, security policies and models, the inference problem, and multilevel database concurrency control.

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**Title:** A Taxonomy of Computer Program Security Flaws, with Examples  
**Author(s):** Carl E. Landwehr, Alan R. Bull, John P. McDermott, and William S. Choi  
**E-mail Address:** landwehr@itd.nrl.navy.mil  
**Citation:** NRL Formal Report, NRL/FR/5542--93-9591  
**Date:** November 19, 1993  
**Report No.:** CCHAS-93-025

**Abstract:**

An organized record of actual flaws can be useful to designers, implementors, and evaluators of computer systems. This paper provides a taxonomy for computer program security flaws together with an appendix that carefully documents 50 actual security flaws. These flaws have all been described previously in the open literature, but in widely separated places. For those new to the field of computer security, they provide a good introduction to the characteristics of security flaws and how they can arise. Because these flaws were not randomly selected from a valid statistical sample of such flaws we make no strong claims concerning the likely distribution of actual security flaws within the taxonomy. However, this taxonomy can be used to organize and abstract more representative samples. Data organized this way could be used to focus efforts to remove security flaws and prevent their introduction.

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**Title:** A Pump For Rapid, Reliable, Secure Communication  
**Author(s):** Myong H. Kang and Ira S. Moskowitz  
**E-mail Address:** mkang@itd.nrl.navy.mil.  
**Citation:** First ACM Conference on Computer and Communication Security, 119-129, ACM Press  
**Date:** November 1993  
**Report No.:** CCHAS-93-026

**Abstract:**

Communication from a low to a high-level system without acknowledgments will be unreliable; with acknowledgments, it can be insecure. We propose to provide quantifiable security, acceptable reliability, and minimal performance penalties by interposing a device (called the Pump to push messages to the high system and provide a controlled stream of acknowledgments to the low system).

This paper describes how the Pump supports the transmission of messages upward and limits the capacity of the covert timing channel in the acknowledgment stream without affecting the average acknowledgment delay seen by the low system or the message delivery delay seen by the high system in the absence of actual Trojan horses. By adding random delays to the acknowledgment stream when the Pump's message buffer is full, we show how to further reduce the covert channel capacity even in the presence of cooperating Trojan horses in both the high and low systems. We also discuss engineering tradeoffs relevant to practical use of the Pump.

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**Title:** COMPUSEC, A Personal View

**Author(s):** Herman O. Lubbes

**E-mail Address:** lubbes@itd.nrl.navy.mil.

**Citation:** Proceedings of the 9th Annual Computer Security Applications Conference, X-XVIII, IEEE Press

**Date:** December 1993

**Report No.:** CCHAS-93-027

**Abstract:**

This paper expresses a personal view of the state of computer security technology and its practice based on twenty years of experience. The paper contains a discussion of some of the events and concepts that have influenced the technology, a discussion of how computer system architecture's have changed, creating gaps in our knowledge about how to design and certify multilevel secure computer systems, and a discussion about certain myths that have grown up about the design and implementation of multilevel systems. A personal assessment of our progress in computer security and a discussion about emerging system level computer security approaches are offered.

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**Title:** Adding Time to a Logic of Authentication

**Author(s):** Paul F. Syverson

**E-mail Address:** syverson@itd.nrl.navy.mil.

**Citation:** Proceedings of the of the First ACM Conference on Computer and Communications Security, 97-101, ACM Press

**Date:** November 1993

**Report No.:** CCHAS-93-028

**Abstract:**

In [BAN89] Burrows, Abadi, and Needham presented a logic (BAN) for analyzing cryptographic protocols in terms of belief. This logic is quite useful in uncovering flaws in protocols; however, it also has produced confusion and controversy. Much of the confusion was cleared up when Abadi and Tuttle provided a semantics for a version of that logic (T) in [AT91].

In this paper we present a protocol to show that both BAN and AT are not expressive enough to capture all of the kinds of flaws that appear to be within their scope. We then present a logic that adds temporal formalisms to AT and that is rich enough to reveal the flaws in the presented protocol; nonetheless, this logic is sound with respect to the same semantics that was given in [AT91]. Finally, we argue that any approach of this type is inadequate by itself to demonstrate the absence of such flaws. We must supplement the formal logic with semantic analysis techniques.

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**Title:** Toward a Mathematical Foundation for Information Flow Security

**Author(s):** James W. Gray, III,

**E-mail Address:** gray@cs.ust.hk

**Citation:** Journal of Computer Security, v1, n3, 255-294

**Date:** 1993

**Report No.:** CCHAS-93-0029

**Abstract:**

We describe a general purpose, probabilistic system model that can be used to model a large class of probabilistic (as well as deterministic) computer systems. We develop the necessary probability theory to rigorously state and reason about properties of probabilistic systems. We give two definitions of information flow security that make use of this model. The first is based on Goguen and Meseguer's Noninterference; the second

is based on McLean's FM. We prove that the second definition is strictly stronger than the first and give verification conditions for both definitions. Finally, we show some relationships between these definitions and other definitions in the literature, including definitions from classical information theory.

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**Title:** Knowledge, Belief, and Semantics in the Analysis of Cryptographic Protocols

**Author(s):** Paul F. Syverson

**E-mail Address:** Syverson@itd.nrl.navy.mil

**Citation:** Journal of Computer Security, v1, n3, 317-334

**Date:** 1993

**Report No.:** CCHAS-93-030

**Abstract:**

We resolve a debate over the appropriateness for cryptographic protocol analysis of formalisms representing knowledge vs. those representing belief by showing that they are equally adequate for protocol analysis on the logical level. We discuss the significance of semantics for logics of cryptographic protocols. In particular, we look at semantics as a measure of a logic and as a reasoning tool in its own right. To illustrate the value of a semantics we use the semantics given in [AT91] to resolve a debate over an alleged flaw in the logic of [BAN89].

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**Title:** TAMPS Key Manager Functional Requirements

**Author(s):** Matthew J. Fierst

**E-mail Address:** fierst@itd.nrl.navy.mil

**Citation:** NRL Memorandum Report, NRL/MR/5541--93-7370

**Date:** July 27, 1993

**Report No.:** CCHAS-93-031

**Abstract:**

The Tactical Aircraft Mission Planning System (TAMPS) is an existing system used by Naval aviators to aid in mission preparation. The TAMPS computer allows users to access various databases including terrain, mapping, photographic intelligence, and threat summaries to obtain information relevant to their assigned objectives. It also provides automated tools for generating flight plans and setting other mission-related parameters, for the aircraft as well as for the weapons systems it will be carrying. To aid in mission execution, the data files created by TAMPS computer can be transported to the aircraft via data transfer cartridges. Immediately prior to launch, the aircraft can read the data files from the cartridge, initialize its avionics systems, and forward the appropriate files to the destination weapons systems.

Some of the weapons systems supported by TAMPS incorporate Global Positioning System (GPS) receivers. In order to take full advantage of the GPS Precise Positioning Service, these receivers must be loaded with cryptographic keys. It is therefore desired to place these keys on the data transfer cartridges along with the mission data for the weapons systems. However, due to handling restrictions on GPS keys, it is not feasible to process them using the TAMPS computer. The KEY Manger(KM) is therefore being developed to add GPS keys to TAMPS-generated mission data on data transfer cartridges. This document addressed the baseline functionality required in the KM. It begins by summarizing the assumptions and requirements placed on the TAMPS computer in order to coordinate cartridge handling procedures. The document then presents the high-level functional requirements for the KM, based on the need to add keys to cartridges while at the same time minimizing the risk of compromising those keys. The document concludes with a brief description of the subsequent development process planned for the KM.

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**1993 TECHNICAL REPORT ORDER FORM**  
**Center for Computer High Assurance Systems, Code 5540**

- [ ] **CCHAS-93-001** A Practical Transaction Model and Untrusted Transaction Manager for a Multilevel-Secure Database System, *Myong H. Kang, Oliver Costich, and Judith N. Froscher*
- [ ] **CCHAS-93-002** Orange Locking: Channel-Free Database Concurrency Control via Locking, *John P. McDermott and Sushil Jajodia*
- [ ] **CCHAS-93-003** A Logical Language for Specifying Cryptographic Protocol, *Paul F. Syverson*
- [ ] **CCHAS-93-004** On Introducing Noise into the Bus-Contention Channel, *James W. Gray, III*
- [ ] **CCHAS-93-005** On Analyzing the Bus-Contention Channel Under Fuzzy Time, *James W. Gray, III*
- [ ] **CCHAS-93-006** Comparing Different Approaches for Specifying and Verifying Real-Time Systems, *C. Heitmeyer, R. Jeffords and B. Labaw*
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- [ ] **CCHAS-93-011** Models of Confidentiality: Past, Present, and Future, *John D. McLean*
- [ ] **CCHAS-93-012** Performance Analysis of Transaction Management Algorithms for the SINTRA Replicated-Architecture Database System, *John P. McDermott and Ravi Mukkamala*
- [ ] **CCHAS-93-013** An International Survey of Industrial Application of Formal Methods: Purpose, Approach, Analysis, and Conclusions, *D. Craigen, S. Gerhart and T. Ralston*
- [ ] **CCHAS-93-014** An International Survey of Industrial Application of Formal Methods: Case Studies, *D. Craigen, S. Gerhart and T. Ralston*
- [ ] **CCHAS-93-015** Maintaining Multilevel Transaction Atomicity in MLS Database Systems with Kernelized Architecture, *Oliver Costich and Sushil Jajodia*
- [ ] **CCHAS-93-016** Applying Formal Methods to an Embedded Real-Time Avionics System, *P. Clements, C. Heitmeyer and B. Labaw*

- [ ] **CCHAS-93-017** Design Documentation for the SINTRA Global Scheduler, *Myong H. Kang and Rodney Peyton*
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- [ ] **CCHAS-93-019** Integrating Specifications, Integrating Assurances, *John D. McLean*
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- [ ] **CCHAS-93-023** On Key Distribution Protocols for Repeated Authentication, *Paul F. Syverson*
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- [ ] **CCHAS-93-026** A Pump For Rapid, Reliable, Secure Communication, *Myong H. Kang and Ira S. Moskowitz*
- [ ] **CCHAS-93-027** COMPUSEC, A Personal View, *Herman O. Lübkes*
- [ ] **CCHAS-93-028** Adding Time to a Logic of Authentication, *Paul F. Syverson*
- [ ] **CCHAS-93-029** Toward a Mathematical Foundation for Information Flow Security, *James W. Gray, III*
- [ ] **CCHAS-93-030** Knowledge, Belief, and Semantics in the Analysis of Cryptographic Protocols, *Paul F. Syverson*
- [ ] **CCHAS-93-031** TAMPS Key Manager Functional Requirements, *Matthew J. Fierst*

**1992 TECHNICAL REPORT ORDER FORM**  
**Center for Computer High Assurance Systems, Code 5540**

- [ ] **5540-92-001** A Single-Level Scheduler for the Replicated Architecture for Multilevel-Secure Databases, *John P. McDermott*
- [ ] **5540-92-002** Using Traces of Procedure Calls to Reason About Composability, *Catherine A. Meadows*
- [ ] **5540-92-003** The Influence Of Delay Upon An Idealized Channel's Bandwidth, *Ira S. Moskowitz and Allen R. Miller*
- [ ] **5540-92-004** A Logical Approach to Multilevel Security of Probabilistic Systems, *James W. Gray, III and Paul F. Syverson*
- [ ] **5540-92-005** A Multilevel Transaction Problem for Multilevel Secure Database Systems and Its Solution for the Replicated Architecture, *Oliver L. Costich and John P. McDermott*
- [ ] **5540-92-006** A Practical Transaction Model and Untrusted Transaction Manager for Multilevel-Secure Database Systems, *Myong Kang, Oliver L. Costich and Judith Froscher*
- [ ] **5540-92-007** Discussion Summary: Fifth IFIP WG 11.3 Working Conference and Meeting, *Catherine A. Meadows*
- [ ] **5540-92-008** A Classical Automata Approach to Noninterference Type Problems, *Ira S. Moskowitz and Oliver L. Costich*
- [ ] **5540-92-009** Data Dependence Analysis for an Untrusted Transaction Manager in a Multilevel Database System, *Myong H. Kang, Henry G. Dietz, and Bharat Bhargava*
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- [ ] **5540-92-011** The Handbook for the Computer Security Certification of Trusted Systems, *Charles Payne and Judith Froscher*
- [ ] **5540-92-012** An Internetwork Authentication Architecture, *Randall J. Atkinson*
- [ ] **5540-92-013** A Comparison of ISDN and LAN Technologies for Shipboard Use, *Randall Atkinson*
- [ ] **5540-92-014** IFIP WG11.3 Database Security: Research Questions of Current Significance, *Carl E. Landwehr*
- [ ] **5542-92-001** The ECA Critical Requirements Model, *Charles Payne, David Mihelcic, Andrew Moore and Kenneth Hayman*



## **VI. TRANSMISSION TECHNOLOGY CODE 5550**

The Transmission Technology Branch conducts a research and development program directed toward the improvement of information transmission and reception between surface, air, submerged and space platforms. The Branch mission includes understanding and developing approaches to satisfy the need for affordable, efficient and robust dissemination of combat management information. In support of this goal, the Branch investigates all aspects of the process of information transfer including the development of state-of-the-art transmission equipment as well as research into antennas and channel propagation phenomena. Emphasis is placed on those aspects of transmission technology that permit adaptation to inhospitable natural or man-made environments. In addition, the Branch conducts research and development in support of signal intercept and related intelligence system projects. Areas of activity include; (1) Wideband HF architecture and RF system engineering, (2) Communication channel characterization including Arctic communication issues, (3) Intercept system analysis, development, and prototype evaluation, (4) Satellite and space communication technology and (5) Research into wideband and compact antenna systems.

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**Title:** An Electromagnetic Interference Study of Potential Transmitter Sites for the HF Active Auroral Research Program (HAARP)  
**Author(s):** Joseph A. Goldstein, Edward J. Kennedy, Adrian S. Eley and Michael A. Rupar  
**E-mail Address:** goldstein@itd.nrl.navy.mil, kennedy@itd.nrl.navy.mil, eley@itd.nrl.navy.mil or rupar@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report #7375  
**Date:** 19 July 1993  
**Report No:** TT-93-001

**Abstract:**

This report presents the results of Electromagnetic Interference (EMI) measurements conducted by the Naval Research Laboratory in June of 1991. This study examined a number of potential sites for the location of the proposed High Frequency Active Auroral Research Program (HAARP) transmitter facility. The proposed HAARP facility will consist of a large planar array of antennas excited by phased high power transmitters operating in the lower portion of the HF band (2.8 to 8 MHz). Several candidate locations were identified for study in the vicinity of Fairbanks, Alaska. The magnitude of EMI in the population centers and on other commercial and public facilities in the vicinity of Fairbanks from the high power transmitter is a major factor in the site selection process for HAARP. The EMI investigations were conducted in two phases. For Phase I of the study, EMI measurements were conducted at two receiver locations using an airborne transmitter at thirteen potential HAARP sites. The results from the Phase I measurements were examined and the two most promising candidate transmitter locations were selected for more comprehensive measurements during Phase II. For Phase II, comprehensive EMI measurements were made for each of the two candidate transmitter sites. Field strengths were measured at a variety of receiver locations that are representative of the impact area for the EMI from HAARP. The results for both the Phase I and Phase II measurements are presented in this report.

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**Title:** Morphology and Characteristics of Disturbed HF Skywave Channels  
**Author(s):** Leonard S. Wagner  
**E-mail Address:** wagner@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report #7389  
**Date:** September 3, 1993  
**Report No:** TT-93-002

**Abstract:**

The normal HF skywave channel is one in which propagation via ionospheric reflection predominates. A disturbed HF skywave channel is defined to be one in which ionospheric scatter plays a significant, often dominant, role in point-to-point radiowave propagation. From a communications perspective, a disturbed channel is one which exhibits reduced signal level in combination with the extensive delay and Doppler spread. Channels which are regularly disturbed include the trans-equatorial, trans-polar and trans-auroral channels. This report covers a number of topics including: (1) measurements that have contributed to our knowledge about the structure and behavior of disturbed channels, (2) solar-terrestrial control factors (e.g., diurnal, seasonal, solar cycle, and geomagnetic), (3) irregularity source regions and current theories of irregularity generation processes, and (4) sample data, available from channel probes, for each of the disturbed channels.

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**Title:** Performance of Adaptive Interference Cancellation in Reducing VHF Interference  
**Author(s):** Adrian S. Eley and John B. Wood  
**E-mail Address:** eley@itd.nrl.navy.mil or wood@itd.nrl.navy.mil  
**Citation:** NRL Memorandum Report #7398  
**Date:** September 3, 1993  
**Report No:** TT-93-003

**Abstract:**

The introduction of tactical frequency hopping VHF radios in the form of the Single Channel Ground and Airborne Radio System (SINCGARS) provides an electronic counter-counter measures capability for friendly forces. This advanced equipment however presents problems for U.S. forces performing electronic warfare missions. On-platform and nearby SINCGARS transmitters can reduce the effectiveness of direction finding (DF) systems by producing temporary, on-frequency energy that confuses current processing algorithms. Additionally, these transmitted signals can overload RF processing components and produce distortion that makes it difficult to accurately detect signals-of-interest. The Naval Research Laboratory (NRL) evaluated one technique that was shown capable of providing receiving system protection from colocated transmitted signals. This technique, referred to as adaptive interference cancellation (AIC), is based on the subtraction of a sample of the on-platform interfering signal generated by the transmitter from the same signal as received by the DF system antennas. This report describes NRL's investigation of the AIC technique on the Army's TSQ-138, and provides test data showing cancellation of the SINCGARS waveform on that platform.

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**Title:** Northern Exposure 92: An Investigation of Transauroral HF Radio Skywave Propagation  
**Author(s):** Leonard S. Wagner, Joseph A. Goldstein, Michael A. Rupar and Edward J. Kennedy  
**E-mail Address:** wagner@itd.nrl.navy.mil, goldstein@itd.nrl.navy.mil, rupar@itd.nrl.navy.mil or kennedy@itd.nrl.navy.mil  
**Citation:** NRL Formal Report #9575  
**Date:** 29 September 1993  
**Report No:** TT-93-004

**Abstract:**

The primary objective of the Northern Exposure 92 campaign was to assist in the evaluation of the performance capabilities of a wideband, high frequency, Rake radio receiver on a transauroral skywave channel. A review of the data collected on the transauroral channel during the Northern Exposure 92 exercises indicates that one is likely to encounter three types of signals on the channel: (1) a strong, specularly reflected signal characterized by the usual ionospheric dispersive delay spread and negligible Doppler spread, (2) strong specular multipath signals, exhibiting extensive delay and Doppler spread, and (3) weak scatter signals, exhibiting the widest delay and Doppler spreads. The nonspread reflected signals are encountered during magnetically quiet, daytime conditions where the ionosphere may be described as laminar. The strong, specular-multipath signals occur mostly at night and are associated with reflections from large scale irregularities of electron density characterized by strong horizontal gradients capable of "reflecting" signals whose frequencies lie below some equivalent "maximum usable frequency" (MUF) defined by the path, the background ionosphere, and the maximum electron density in the irregularity region. The weak scattered signals occur at night and are associated with volume scatter from the irregular medium. The scattered signals present the greatest challenge to communication systems with amplitudes  $\approx 30$  dB less than those of reflected signals and with 2s Doppler spreads as large as 30 Hz.

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**Title:** Morphology and Characteristics of Disturbed HF Skywave Channels  
**Author(s):** Leonard S. Wagner  
**E-mail Address:** wagner@itd.nrl.navy.mil  
**Citation:** MILCOM '93 Classified Conference Record (U), vI, CL4.2.1-CL4.2.8  
**Date:** 11-14 October 1993  
**Report No:** TT-93-005

**Abstract:**

(U) The normal HF skywave channel is one in which propagation via ionospheric reflection predominates. A disturbed HF skywave channel is defined to be one in which ionospheric scatter plays a significant, often dominant, role in point-to-point radiowave propagation. Channels which are regularly disturbed include the trans-equatorial, trans-polar and trans-auroral channels. The paper discusses a number of topics including: (1) measurements that have contributed to our knowledge about the structure and behavior of disturbed channels, (2) solar-terrestrial control factors (e.g. diurnal, seasonal, solar cycle, and geomagnetic), (3) irregularity source regions and current theories of irregularity generation processes and (4) available channel probe data for each of the disturbed channels.

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**Title:** Time Evolution of the High-Latitude HF Channel Scattering Function: A Movie Presentation  
**Author(s):** C. A. Nissen, Leonard S. Wagner, Joseph A. Goldstein and Michael A. Rugar  
**E-mail Address:** wagner@itd.nrl.navy.mil, goldstein@itd.nrl.navy.mil, or rugar@itd.nrl.navy.mil  
**Citation:** MILCOM '93 Classified Conference Record (U), vI, CL4.3.1-CL4.3.7  
**Date:** 11-14 October 1993  
**Report No:** TT-93-006

**Abstract:**

(U) The scattering function is a concept that arises in the modeling of random time-variant scatter-type channels such as the high-latitude HF skywave channel. It expresses in functional form the power density of scattered power as a function of time delay and Doppler frequency. The delay spread introduced by the channel is associated with the random spatial distribution of the scatterers and the Doppler spread is related to the random motion of individual scatterers. The scattering function, in a pure sense, is defined for a wide sense stationary uncorrelated scattering channel and as such is obtained by averaging over all possible realizations of the process.

(U) Approximations to the high-frequency (HF) channel scattering function, based on extensive measurements of real channels, have been published by NRL, SRI and MITRE. These consist primarily of periodogram "snapshot" representations of the channel scattering function relevant to a specific moment in time (process outcome). New insights regarding the actual physical processes underway in the propagation medium, and for the dynamics of the channel with which real systems must cope, is provided by a visual representation of the time evolution of the channel scattering function. This paper presents, for the first time, a movie of the measured scattering function as it evolves over a 23-minute period. In addition, cumulative distribution functions of the rms values of parameters used to characterize the channel will be presented. The data used in this presentation were acquired by the Naval Research Laboratory on a 1300 kilometer path between Greenland and Iceland over a three-week period in March/April 1992. Generation of the time-evolution sequences was performed by MITRE; processing of the data in support of generating the scattering function plots was accomplished with some assistance from software provided by NRL.

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**Title:** Wideband HF RAKE Modem Performance on a Trans-Auroral Scatter Channel  
**Author(s):** Leonard S. Wagner, Joseph A. Goldstein, Michael A. Rugar, Richard R. Kurth and M. T. Lyons  
**E-mail Address:** wagner@itd.nrl.navy.mil, goldstein@itd.nrl.navy.mil, or rugar@itd.nrl.navy.mil  
**Citation:** MILCOM '93 Classified Conference Record (U), VII, CL12.2.1-CL12.2.5  
**Date:** 11-14 October 1993  
**Report No:** TT-93-007

**Abstract:**

(U) The theoretical performance improvement afforded by direct-sequence spread-spectrum HF communications technology over the well-known limitations of narrowband HF skywave systems has been validated experimentally over the past decade on a variety of mid-latitude HF links. The potential of wideband HF also extends to more severe propagation conditions, i.e., on links with delay and Doppler spreading characteristics not usually encountered at middle latitudes. This paper presents experimental results involving simultaneous wideband HF radio operation and channel probe measurements on a high-latitude path via trans-auroral scatter propagation. Direct-sequence HF transmissions were processed by a RAKE receiver over a 1300 km link between Sondrestrom, Greenland and Keflavik, Iceland. Continuous wideband channel probing at adjacent frequencies measured signal-to-noise ratio, delay spread, and Doppler spread during the communications tests. Results of a particular experiment are highlighted, representing some of the most difficult channel conditions encountered during the test period.

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**Title:** Power Dependence Effects Observed in High Temperature Superconductors  
**Author(s):** John B. Wood and Charles E. Hobbis  
**E-mail Address:** wood@itd.nrl.navy.mil  
**Citation:** NRL Formal Report # 9708  
**Date:** December 1993  
**Report No:** TT-93-008

**Abstract:**

Power dependence effects that establish variation in unloaded Q and amplitude of self-generated intermodulation products have been measured in two samples of high temperature superconductor material. The two samples were spiral inductors of YBCO deposited on a lanthanum aluminate substrate and measurements were performed at the self resonant frequency of about 36 MHz. The sample that had received a passivation treatment was observed to have superior Q and distortion characteristics. Q factors as high as  $4 \times 10^4$  were observed. Above current densities of about  $0.13 \times 10^6$  amp/cm<sup>2</sup> Q degraded rapidly. A current density of about  $0.07 \times 10^6$  amp/cm<sup>2</sup> resulted in third order distortion of about -40 dBc. Although this performance may be acceptable for low power applications, much better materials are required to support development of some high power applications such as matching networks for use with electrically small transmitting antennas. Advances in companion technologies are needed also if rapid tunability is required.

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**1993 TECHNICAL REPORT ORDER FORM**  
**Transmission Technology, Code 5550**

- [ ] **TT-93-001** An Electromagnetic Interference Study of Potential Transmitter Sites for the HF Active Auroral Research Program (HAARP), *Joseph A. Goldstein, Edward J. Kennedy, Adrian S. Eley and Michael A. Rugar*
- [ ] **TT-93-002** Morphology and Characteristics of Disturbed HF Skywave Channels, *Leonard S. Wagner*
- [ ] **TT-93-003** Performance of Adaptive Interference Cancellation in Reducing VHF Interference, *Adrian S. Eley and John B. Wood*
- [ ] **TT-93-004** Northern Exposure 92: An Investigation of Transauroral HF Radio Skywave Propagation, *Leonard S. Wagner, Joseph A. Goldstein, Michael A. Rugar and Edward J. Kennedy*
- [ ] **TT-93-005** Morphology and Characteristics of Disturbed HF Skywave Channels, *Leonard S. Wagner*
- [ ] **TT-93-006** Time Evolution of the High-Latitude HF Channel Scattering Function: A Movie Presentation, *C. A. Nissen, Leonard S. Wagner, Joseph A. Goldstein and Michael A. Rugar*
- [ ] **TT-93-007** Wideband HF RAKE Modem Performance on a Trans-Auroral Scatter Channel, *Leonard S. Wagner, Joseph A. Goldstein, Michael A. Rugar, Richard R. Kurth and M. T. Lyons*
- [ ] **TT-93-008** Power Dependence Effects Observed in High Temperature Superconductors, *John B. Wood and Charles E. Hobbis*

**1992 TECHNICAL REPORT ORDER FORM**  
**Transmission Technology, Code 5550**

- [ ] **TT-92-001** Proceedings of the Workshop on Integrated Cryogenic Satellite Design: Current Practice and Future Possibilities, *J. Choi*
- [ ] **TT-92-002** Radial Ground Screen Design for a Vertical Monopole, *M.A. Rugar*

## VII. ADVANCED INFORMATION TECHNOLOGY CODE 5580

The Advanced Information Technology Branch of the Information Technology Division develops and implements cutting edge hardware and software solutions for Navy problems in a number of application areas. Current research and development thrusts include:

- parallel and distributed hardware, software and display technologies;
- novel signal processing techniques directed primarily toward the exploitation of massively parallel systems;
- development of hardware independent systems for developing and porting code for parallel processing systems;
- design and implementation of reactive and interactive control systems;
- development of technologies for decision support systems and prototyping of all varieties of decision systems including tactical decision aids and mission planning;
- exploration and demonstration of new methods for data management including data fusion, design and navigation of database systems, and correlation and tracking of current and historical information; and display technologies for visual management of *all of the above applications*.

The technical programs in the Branch include some basic research (6.1), a substantial exploratory development program (6.2) and a continuing effort to field technology through a succession of advanced technology demonstrations (6.3a). The Branch draws on expertise in computer science, mathematics, operations research, electrical engineering and physics.

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**Title:** A Cellular Automaton Methodology for Solving the Wave Equation  
**Author(s):** J. B. Cole, R. Krutar, D. B. Creamer, and Susan K. Numrich  
**E-mail Address:** cole@ait.nrl.navy.mil  
**Citation:** Proceedings of the 7th ACM/SIGARCH International Conference on Supercomputing, Tokyo, Japan  
**Date:** 20-22 July 1993  
**Report No.:** AT-93-001

**Abstract**

We describe a parallel finite difference algorithm in the form of a cellular automaton for solving the full form of the wave equation. Since we do not use the far field approximation, this algorithm is particularly effective for solving near-and intermediate field problems. Problems are solved in the time domain and real time animated displays show the field evolution. The algorithm is perfectly matched to the architecture of "single instruction multiple data" (SIMD) parallel processors. On the CM-200, for example, it typically takes several minutes to compute wave fields and display them on a 512X512 grid. A good personal computer, however, is sufficient to develop many interesting classroom demonstrations of wave propagation phenomena.

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**Title:** A Nearly Exact Second Order Finite Difference Wave Propagation Algorithm on a Coarse Grid  
**Author(s):** James B. Cole  
**E-mail Address:** cole@ait.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** October 20, 1993  
**Report No.:** AT-93-002

**Abstract**

We introduce a new second order finite difference algorithm to solve the wave equation on a coarse grid with a solution error that is less than  $10^{-4}$  that of the conventional algorithm. To attain the same accuracy that the new algorithm delivers at  $l/h$  (grid units per wavelength) = 8, the conventional algorithm would have to use  $l/h = 1140$ . In addition, our algorithm requires approximately 22% fewer iterations in two dimensions, and 39% fewer in three to solve a given problem. The algorithm is based on a very nearly isotropic finite difference Laplacian. The methodology used to construct this Laplacian can also be used to derive isotropic finite difference gradient and divergence operators.

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**Title:** A Cellular Automaton Algorithm for Time-Domain Simulation and Visualization of Wave Propagation  
**Author(s):** J.B. Cole, R.A. Krutar, D.B. Creamer and S.K. Numrich  
**E-mail Address:** cole@ait.nrl.navy.mil  
**Citation:** Internal Report  
**Date:** October 20, 1993  
**Report No.:** AT-93-003

**Abstract**

We describe a parallel finite difference algorithm in the form of a cellular automaton based on a grid realization of Huygens' principle for simulating wave propagation and scattering in the time domain. As the iteration proceeds, real time animated displays depict the field evolution. The algorithm is derived from the full form of the wave equation (no simplifications such as the far field approximation) and is particularly effective for near-and intermediate field problems. Cellular automata computations are intrinsically parallel and are well matched to the architecture of "single instruction multiple data" (SIMD) parallel



processors. On the CM-200 for example, it takes only a few minutes to compute and display several thousand iterations of a wave field on a 512X512 grid. A good personal computer, however, is sufficient to develop many interesting classroom demonstrations of wave propagation phenomena.

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**Title:** Neural Networks: An NRL Perspective

**Author(s):** Chip Backmann, Paul Bey, Jeremy Broughton, Victor Chen, Sheldon Gardner, Behrooz Kamgar-Parsi, Behzad Kamgar-Parsi, Moon Kim, Francis Kub, Keith Moon, Abraham Schultz, John Sciortino, Dean Scribner, Andrew Skinner, William Tolles, Jeff Willey and Sheldon Wolk

**E-mail Address:** behzad@ait.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/1003-93-7396

**Date:** September 3, 1993

**Report No.:** AT-93-004

**Abstract**

The subject of neural networks is introduced as a brief review and to provide perspective to the subject. A number of programs at the Naval Research Laboratory (NRL) are outlined to describe the general approach used and the anticipated benefits of neural networks. Observations and recommendations concerning the subject are made on the subject. This document serves as a base of information for additional internal discussions concerning opportunities for neural networks within NRL.

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**Title:** Undersea Visualization: a Tool for Scientific and Engineering Progress

**Author(s):** L. J. Rosenblum, W. K. Stewart, and Behzad Kamgar-Parsi

**E-mail Address:** behzad@ait.nrl.navy.mil

**Citation:** Book Chapter, Chapter 1, Animation and Scientific Visualization, edited by Earnshaw and Watson, Academic Press

**Date:** November 1993

**Report No:** AT-93-005

**Abstract**

For both remote imaging and on-site measurement the undersea environment is perhaps the most inhospitable known to man. The inability of most forms of energy to penetrate the ocean sufficiently to provide detailed measurements leads to a reliance of acoustical sensors for remote sensing. Because of the comparatively low acoustical frequencies and often uncertain navigational information, resolution is poor and measurements sparse. This in turn leads to unique problems in visualization and imaging. Overcoming these limitations to obtain reasonable images typically requires an integration of digital imaging with visualization techniques. This paper uses data from several ocean-science domains to illustrate how visualization is used to extract knowledge from data.

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**Title:** 3D Acoustic Imaging with a Thin Lens  
**Author(s):** B. Johnson, D. Scroggins, D. Folds, Behzad Kamgar-Parsi and E. Belcher  
**E-mail Address:** behzad@ait.nrl.navy.mil  
**Citation:** Proceedings of the Oceans 93 Conference, Vancouver, BC  
**Date:** October 18-21, 1993  
**Report No:** AT-93-006

**Abstract**

Too often, underwater video, photographic, and laser images are obscured by turbid water. Acoustic systems that are able to pass energy through turbid water typically generate images with insufficient resolution and contrast. This paper discusses an experiment that provided satisfactory images of objects at short range using acoustic energy at 3 MHz. The imaged objects had different shapes (cylinders and plates) with small features such as bolt patterns and ribs. The experiment took place in an acoustic tank with objects 1.8 meters in front of a bi-concave, thin lens 20 cm in diameter. The lens generated a conical, focused beam 0.16 between the -3 dB points with side lobes more than 50 dB below the main lobe. The system mechanically scanned and interrogated the targets at 0.5 cm intervals from left to right and from top to bottom. Targets were imaged in 3-D perspective with clearly distinguished bolt patterns and ribs. The paper compares images acquired in different levels of water turbidity and with different beam patterns and different image processing techniques.

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**Title:** Applying Monte Carlo Methods On The Connection Machine To Simulate Photon Propagation In the Ocean  
**Author(s):** Jerry L. Gorline  
**E-mail Address:** gorline@ait.nrl.navy.mil  
**Citation:** NRL Memorandum Report NRL/MR/5580-93-7377  
**Date:** July 16, 1993  
**Report No:** AT-93-007

**Abstract**

Light propagation in the ocean is a complex process involving multiple scattering and absorption. Analytic solutions have been developed but only account for single scattering. Multiple scattering must be included in any realistic model concerning the attenuation of light in the ocean. Monte Carlo methods have been used to develop models that include multiple scattering and have provided encouraging results. In this paper I will describe the Monte Carlo model that was developed to simulate photon propagation in the ocean. I will also discuss the methods employed to take advantage of the parallel environment of the Connection Machine. This model will be used in the future to solve various problems in ocean optics.

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**Title:** Radar Modeling For Strike Warfare Decision Aids  
**Author(s):** Miguel R. Zuniga, Jeffrey K. Uhlmann and James B. Hofmann  
**E-mail Address:** zuniga@ait.nrl.navy.mil  
**Citation:** 10th Annual Conference for Command and Control Decision Aids, Washington DC  
**Date:** July 1, 1993  
**Report No:** AT-93-008

**Abstract**

Some decision aid tools use asset routers (path optimizers) that rely on graphs (sets of nodes and edges) to represent the problem domain. Graph theoretic representation puts requirements and constraints on the modeling, and so models appropriate to the

representation must be created. For illustration and because of its importance, we focus on modeling the radar-airplane interactions in developing routes for strike warfare decision aids. Beginning with a common simulation model, we formulate a model that is appropriate (both fast and realistic enough) for use with graphs. The model uses a standard probability of instantaneous detection along with an additional and necessary irradiation probability. We also highlight some potential limitations of graph based routers, e.g. despite the fact that a radar is a dynamic system, current implementations of the graphs are not dynamic and may have problems faithfully representing the scanning movement of the radar. Since the routers are to be used by decision aid tools, consideration is given to algorithm CPU time and its improvement, particularly through model selection, gating and factorization methods.

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**Title:** Application of the Hough Transform to Broadband Multipath Interference Patterns for Passive Detection

**Author(s):** Richard Stevens and William Smith

**E-mail Address:** stevens@ait.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/5583-93-7361

**Date:** July 15, 1993

**Report No.:** AT-93-09

**Abstract**

Broadband multipath interference patterns in acoustic Lofargrams can be detected by means of an extended Hough Transform. The broadband multipath interference pattern from a source moving on a steady course comprises a family of curves that can be closely approximated by hyperbolas. Each hyperbola is identified by three parameters, of which two parameters specify the family of hyperbolas and the third parameter specifies the individual hyperbola in the family. A Hough Transform maps each hyperbola in the Logargram to a single point in the 3-dimensional parameter space. The energies of the hyperbola in each family are then summed, yielding a 2-dimensional image of the resulting sums. This image is then searched for peaks.

This paper describes the use of the Hough Transform to detect families of hyperbolas. Included are a derivation of the near hyperbolic form of the curves in the interference pattern, the algorithm used in the Hough Transform, some results of procession synthetic data and real data, preprocessing and postprocessing, analysis of potential gain, and plans for future investigation.

**Title:** Application of the Hough Transform to Acoustic Broadband Correlograms for Passive Detection and Location

**Author(s):** Richard Stevens and Howard Shyu

**E-mail Address:** stevens@ait.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/5580-92-7182

**Date:** January 7, 1993

**Report No.:** AT-93-010

**Abstract**

An algorithm that provides the dynamics (course and speed) of multiple moving vehicles is derived. Based on the Hough Transform, this algorithm can detect and recognize the delay curves in the acoustic broadband correlogram. The proposed approach can extract the timing of the Closest Point of Approach (CPA), the ratio of target speed to range at the CPA and the track direction for one or more targets.

This algorithm falls into the category of integration-before-detection techniques and hence can be viewed as a coherent integration process. The proposed approach has two stages: 1) accumulating cross-correlation to form a correlogram which serves as the

memory for the integration process and 2) detection through the Hough Transform which serves as a combined parameter estimator and signal detector.

Properties of the delay curves are discussed in both the correlogram space and the Hough space. Some limitations and constraints on the application of the Hough Transform to these curves are discussed.

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**Title:** The Advanced Processor Technology Testbed

**Author(s):** Wendell L. Anderson and William R. Smith

**E-mail Address:** wanderso@ait.nrl.navy.mil

**Citation:** NRL Memorandum Report NRL/MR/5582-93-7329

**Date:** May 21, 1993

**Report No.:** AT-93-011

**Abstract**

An advanced Processing Testbed has been implemented on the NRL Connection Machine 200, a single-instruction multiple data (SIMD) parallel computer. This testbed is capable of performing LOFARgram analysis and broadband correlation using either conventional or adaptive beamforming on data collected from hydrophone arrays. The testbed is implemented as a set of C-language programs that call CM Paris instructions to perform the desired operations on the Connection Machine. Listings of these routines are provided in the appendices. Analysis of the processing time involved in this demonstration indicates that a fully configured 64K processor Connection Machine is capable of processing data at a rate of 1.5 Gigafllops.

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**Title:** An Overview of the Processing Graph Support Environment

**Author(s):** Roger Hillson

**E-mail Address:** hillson@ait.nrl.navy.mil

**Citation:** Proceedings of the 1993 Complex Systems Engineering Synthesis and Assessment Technology Workshop (CSESAW 93)

**Date:** July 20-22, 1993

**Report No.:** AT-93-012

**Abstract**

The Navy has developed a data flow method for programming networks of processors. This approach, called the Processing Graph Method (PGM), is now being used to develop signal processing applications for the Navy's second-generation tactical signal processor. At the Naval Research Laboratory, a unified set of software tools has been developed to facilitate PGM programming. A Macintosh-based Graphic Entry Workstation (GEWS) can be used to iconically capture processing graphs which are then automatically translated into Signal Processing Graph Notation (SPGN). The Processing Graph Support Environment (PGSE) is a set of Ada software utilities for compiling, linking, and executing the processing graphs; it includes a large, user-extensible library of signal processing primitives. PGSE is now available for VAX systems running VMS and for Sun-4 workstations under SUN OS 4.1.3. A simple signal processing application is developed to demonstrate the utility of PGSE, and current enhancements to the system are discussed. GEWS and PGSE are both available from the Naval Research Laboratory.

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**Title:** Computation of Acoustic Fields on a Massively Parallel Processor Using Lattice Gas Method

**Author(s):** S. K. Numrich, R. A. Krutar and R. Squier

**E-mail Address:** numrich@ait.nrl.navy.mil

**Citation:** Proceedings of the 3rd IMACS Symposium on Computational Acoustics, Cambridge, MA, USA, v1 "Scattering, Supercomputing, and Propagation" IMACS, Elsevier Science Publishers, North-Holland, New York

**Date:** c1993

**Report No.:** AT-93-013

**Abstract**

We have begun to explore lattice gas methods in the computation of acoustic field behavior. The model being implemented was developed by Hudong Chen, Shiyi Chen, Gary Doolen and Y. C. Lee as a solution to the wave equation and was redesigned for the Connection Machine by an NRL research team. In addition to providing a parallel implementation, we have added the ability to model independently driven point sources, each with its own amplitude, frequency and phase. These sources have been used to test new array configurations as well as replicate familiar beam patterns for shaded and unshaded arrays. The model can handle both rigid and pressure release boundary conditions and has been adapted to permit changes in sound speed. Lattice gas methods develop global field behavior through defining only local interactions. Once physical behavior, a pressure release boundary, for example, has been correctly modeled by these local interactions, it can be placed as isolated points or aggregates in any chosen geometry at any position in the field, and replicated as often as desired. As an illustration, we have modeled the interaction of a propagating sound field through a random distribution of pressure release points in imitation of a school of fish. The output of the model shows the two-dimensional evolution of the sound field as it emerges from the source array, encounters the biological clutter and propagates partially through and is scattered by the distribution of modeled swim bladders.

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**1993 TECHNICAL REPORT ORDER FORM**  
**Advanced Information Technology, Code 5580**

- [ ] **AT-93-001** A Cellular Automaton Methodology for Solving the Wave Equation, *J. B. Cole, R. Krutar, D. B. Creamer, and Susan K. Numrich*
- [ ] **AT-93-002** A Nearly Exact Second Order Finite Difference Wave Propagation Algorithm on a Coarse Grid, *James B. Cole*
- [ ] **AT-93-003** A Cellular Automaton Algorithm for Time-Domain Simulation and Visualization of Wave Propagation, *J. B. Cole, R. A. Krutar, D. B. Creamer and S. K. Numrich*
- [ ] **AT-93-004** Neural Networks: An NRL Perspective, *Chip Backmann, Paul Bey, et al.*
- [ ] **AT-93-005** Undersea Visualization: a Tool for Scientific and Engineering Progress, *L. J. Rosenblum, W. K. Stewart, and Behzad Kamgar-Parsi*
- [ ] **AT-93-006** 3D Acoustic Imaging with a Thin Lens, *B. Johnson, D. Scroggins, D. Folds, Behzad Kamgar-Parsi and E. Belcher*
- [ ] **AT-93-007** Applying Monte Carlo Methods On The Connection Machine To Simulate Photon Propagation In the Ocean, *Jerry L. Gorline*
- [ ] **AT-93-008** Radar Modeling For Strike Warfare Decision Aids, *Miguel R. Zuniga, Jeffrey K. Uhlmann and James B. Hofmann*
- [ ] **AT-93-09** Application of the Hough Transform to Broadband Multipath Interference Patterns for Passive Detection, *Richard Stevens and William Smith*
- [ ] **AT-93-010** Application of the Hough Transform to Acoustic Broadband Correlograms for Passive Detection and Location, *Richard Stevens and Howard Shyu*
- [ ] **AT-93-011** The Advanced Processor Technology Testbed, *Wendell L. Anderson and William R. Smith*
- [ ] **AT-93-012** An Overview of the Processing Graph Support Environment, *Roger Hillson*
- [ ] **AT-93-013** Computation of Acoustic Fields on a Massively Parallel Processor Using Lattice Gas Method, *S. K. Numrich, R. A. Krutar and R. Squier*

**1992 TECHNICAL REPORT ORDER FORM**  
**Advanced Information Technology, Code 5580**

- [ ] **AT-92-001** Simulations of Acoustic Fields on a Massively Parallel Computer,  
*S.K. Numrich, R.A. Krutar, D.B. Creamer and J.B. Cole*
- [ ] **AT-92-002** Computation of Acoustic Fields on a Massively Parallel Processor  
Using Lattice GA Methods, *S.K. Numrich, R.A. Krutar and R. Squier*
- [ ] **AT-92-003** Algorithms for Multiple-Target Tracking, *Jeffrey K. Uhlmann*
- [ ] **AT-92-004** A MOD LOC Vulnerability Assessment Tool, *Jeffrey K. Uhlmann*
- [ ] **AT-92-005** Classification of Underwater Targets Using Bayesian Networks,  
*Ranjeev Mittu*
- [ ] **AT-92-006** Implementing Metric Trees to Satisfy General Proximity/Similarity  
Queries, *Jeffrey K. Uhlmann*
- [ ] **AT-92-007** Construction of a Likelihood Function for Information from Active  
Sonar Systems in a Nonlinear Filter, *Becky Mahal*
- [ ] **AT-92-008** Scattering of Sound Pulses and the Ringing of Target Resonances,  
*Susan K. Numrich and Herbert Uberall*

## VIII. CENTER FOR COMPUTATIONAL SCIENCES CODE 5590

The Center for Computational Science, Code 5590, conducts research and development to further the advancement of computing and communications systems to solve Navy problems. The Branch accomplishes this mission through a balanced focus on service, research, and development. The Center is committed to investigating and developing leading edge technologies to establish an advanced computational environment that will benefit all research areas. The Branch studies new technologies to evaluate their potential. Promising technologies are further developed, enhanced, and transitioned to production systems. The Branch's operational efforts provide for a computing environment that emphasizes reliability, high performance, and user productivity. In the area of research and development the Branch develops and implements new technologies, both hardware and software, to solve Navy problems in diverse application areas. Current thrusts include: parallel and distributed hardware, software and display technologies; signal processing techniques directed toward exploitation of massively parallel systems; development of hardware architecture independent systems for developing and porting code for parallel processing; and development of high-speed networks.

In the area of operational support, the Center provides shared high performance computing and networking resources and related services, including user support and training, for NRL, Navy, and DoD interdisciplinary research efforts. The Branch manages and operates NRL's shared massively parallel supercomputer, vector mini-supercomputer, central file server/archive, and scientific visualization systems. The Branch has responsibility for the laboratory's local area network and external connections to network and computer systems world-wide. The Branch also provides laboratory ADP logistic support by identifying ADP requirements and securing and administering contractual support for lab-wide or multiple buys of ADP systems, software and services.

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**Title:** ADP Contract Consolidation...Does It Compute?  
**Author:** John L. Douglas  
**E-mail Address:** douglas1@ccf.nrl.navy.mil  
**Citation:** NRL Memorandum Report NRL/MR/5590-93-0001  
**Date:** October 1, 1993  
**Report No.:** CCS-93-001

**Abstract**

The purpose of this study is to evaluate the NRL ADP Contract Consolidation Program. Participants were asked to respond to a questionnaire concerning their experience and opinions of the NRL-Wide Contracts. Additional information has been drawn from historical data and related literature. The population studied in this research project consisted of Branch Managers and above at the Naval Research Laboratory. These employees are located at the Washington, DC location. A survey questionnaire was forwarded to each manager with a goal of obtaining a 100 percent response.

The survey findings, along with the literature discussed, support the consolidation program, and relate its timeliness to similar occurrences within industry and government. The section on Relevant Evidence discusses the benefits and savings of consolidating contracts and further consolidating programs and contracts under one program manager.

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**1993 TECHNICAL REPORT ORDER FORM**  
**Center for Computational Sciences, Code 5590**

[ ] CCS-93-001 ADP Contract Consolidation...Does It Compute?, *John L. Douglas*